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ELECTRIC IGNITION

COMBUSTION MOTORS

FORREST R. JONES

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PREFACE.

THE plan of this work is based upon the supposition that some of its readers may possibly be unfamiliar with electricity and electrical devices. To meet this condition, the fundamental principles involved in each case are given before commercial forms are described.

The range of the subject matter is from the small ignition apparatus used on motor cycles to that used on the largest gas engines.

More than half of the illustrations have been prepared especially for the book, largely from sketches, drawings, photographs, and information kindly furnished by those making or dealing in ignition appliances.

Electric connections, both internal and external, are shown, by wiring diagrams and other means, for complete ignition systems and the parts of which they are composed.

Considerable attention is given to the operation, care, adjustment, and testing of ignition systems and their various parts. Lack of knowledge in this respect is the chief cause of ignition troubles in connection with the excellent equipments now obtainable.

FORREST R. JONES.

KNOXVILLE, TENNESSEE,
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ELECTRIC IGNITION.

CHAPTER I.

INTRODUCTORY.

1. **Electric ignition,** as applied to motors, or engines, which burn a combustible mixture of gas inside of the cylinder of the motor, is accomplished, in modern practice, either by producing an electric spark, or by drawing an electric arc, inside of the cylinder in the inclosed space which is filled with the combustible mixture. The spark, or arc, as the case may be, ignites the combustible mixture and causes it to burn.

High-tension and Low-tension Electricity.

2. There are two classes of electric ignition as applied to combustion motors. One class is known as high-tension, or jump-spark, ignition; the other class as low-tension, make-and-break, contact, or touch-spark ignition.

The terms " high-tension " and " low-tension " are used in accordance with the intensity of the **tension,** also called **pressure,** of the electricity that is used to produce the spark, or arc, for igniting the combustible charge. An idea of the distinction between high-tension and low-tension electricity as used for ignition can be obtained from its action on the animal, or human, body.

The **high-tension electricity** used for ignition is capable of giving a very severe shock to one who touches the metal of a wire or apparatus which is charged with the high-tension electricity. The shock is not dangerous, however, unless continued for a considerable time.

The **low-tension electricity** for ignition in motors used on automobiles, traction engines, and other similar appliances is

hardly capable of making its presence known by giving a shock to one touching the bare portions of electric conductors charged with it, when ordinary conditions exist. The same is in general true of the electricity used for low-tension ignition in stationary engines when the electricity is supplied by apparatus especially adapted to ignition usage. The pressure of the electricity supplied by such means for low-tension ignition varies considerably in different systems. Some systems operate on about 4 volts, while others operate at about 50 volts. The latter pressure is about the same as that used in some commercial lighting systems, and gives only a slight shock under ordinary conditions. Some stationary engines take electricity from commercial service mains at a pressure of about 110 or even 220 volts. In such cases the electric current is generally passed through incandescent lamps which utilize a portion of the electric pressure and prevent, by their electric resistance, too much current from passing through the ignition apparatus.

The reason that the high-tension electricity used for ignition is not dangerous, although its pressure is several thousand volts, is that the apparatus used does not have capacity to furnish enough electricity to do serious harm. The pressure is enormously high, as compared with that in service wires for incandescent lighting, but the quantity of electricity is minutely small.

The condition of the skin where it comes into contact with an electrically charged metal wire or piece of apparatus has much to do with the extent of the shock that is received, especially when the pressure is as low as that generally used for incandescent lighting and for low-tension ignition. When the skin is dry or oily, the shock is very much less than when it is moist or wet. If the skin is cut or deeply scratched so that the raw flesh comes into contact with the charged metal, then the shock is still more severe than when the skin is intact but wet. The animal skin, or cuticle, offers more resistance to the passage of electricity than the other parts of the body, at least the soft parts. When the skin is removed, more electricity will pass through the body than when the skin is intact, even though moist or wet with water. In other words, a wet skin allows more

electric current to pass through it, on account of its lesser resistance, than will pass through when the skin is dry or oily and consequently offers greater resistance to the passage of electricity.

Sources of Electricity.

3. The **electricity used for ignition** is obtained either from a power-driven machine, called an electric generator, or from an electric battery in which the electricity is produced by chemical action.

When an electric generator has permanent magnets, it is generally called a **magneto.** An electric generator which does not have permanent magnets is ordinarily called either a **dynamo** or an **electromagnetic generator.** Magnetos and electromagnetic generators are both further classified according to the nature of the electricity they produce. This will be taken up in connection with the discussion of electric generators.

Electric batteries are of two distinctive kinds, known as primary and secondary. A secondary battery is also called an electric accumulator and a storage battery.

A **primary battery** is one which is ready to give out electric current as soon as it is constructed.

A **storage battery** cannot give out electric current as soon as it is mechanically constructed, but must have electricity charged into it before it is ready to deliver electric current. It must also be frequently recharged with electricity during its life.

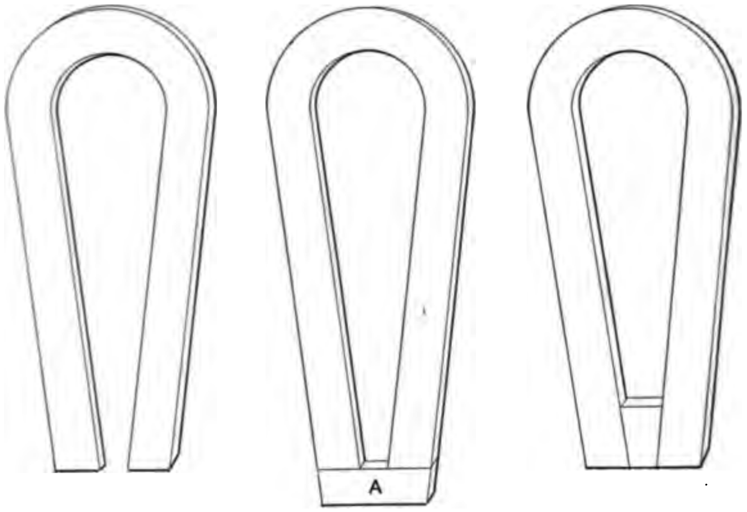
Each unit of which an electric battery is made up is called an electric cell. A primary electric cell is also called a galvanic cell and a voltaic cell, after the names of its inventors. It is quite common practice to call an electric cell a battery, or a battery cell.

Permanent Magnets.

4. **Forms and Action.** — Doubtless the most familiar forms of permanent magnets are the horseshoe magnet and the magnetic needle. The latter is part of the magnetic compass for determining the directions of north and south. Small horseshoe magnets are sold in toy stores and hardware stores. The mag-

netic compass is regularly used on board ocean-going vessels, in surveying instruments, and in pocket compasses.

A common form of horseshoe magnet is shown in Fig. 1. It is made of a piece of bar steel bent to bring the ends of the bar near together. After bending, the steel is first hardened and then magnetized. The magnet will attract pieces of iron and



FIGS. 1, 2, and 3.
Horseshoe Magnets. Permanent.

steel placed near the ends of the bent bar, and, if the pieces are free to move, they will be drawn up against the magnet and held there. It is immaterial what forms the pieces of iron and steel to be attracted have. They may be in the form of wire nails, tacks, balls such as used in ball bearings, rings, or any other form. There is little or no magnetic attraction in the region of the crown, or curve, of the bent bar.

Nails or tacks of comparatively mild steel or soft iron do not remain magnetic to any great extent after they are removed from the magnet. But hardened or tempered pieces of steel, especially those of an elongated form, such as a knife blade, sewing needle, and writing pen, retain considerable magnetism for some time after removal from the magnet, and will pick up

tacks and other small pieces of steel. Still harder pieces of steel, such as a file, will retain magnetism for a longer time than the articles just mentioned.

5. Poles of a Magnet. — The usefulness of the magnetic compass depends on the fact that one end of the magnetic needle, and that always the same end, points approximately in the direction of the north pole of the earth when the needle is allowed to swing freely. The end of the needle which takes its position toward the earth's north pole is called the north pole of the needle; the opposite end, which points toward the south, is called the south pole of the needle.

If a magnetic compass is placed near one of the ends of a horseshoe magnet, the compass needle, if left free to swing, will take a position with one end pointing more or less directly toward the nearest end of the bent bar. For convenience, it will be assumed that the north pole of the compass needle points toward the nearest end of the bent bar. Then, if the compass is moved to a new position so as to bring it near the other end of the bent bar, the needle will swing on its pivot so that the south pole of the needle will point more or less directly toward the nearest end of the bent bar. If the compass is repeatedly moved away from the bent-bar magnet and brought back near it as just described, the north pole of the needle will always be attracted by and point toward the same end of the bent bar, and the south pole will always behave in the same manner relative to the other pole of the bent bar.

In the horseshoe magnet, the bar-end which attracts the north pole of the compass needle is called the south pole of the horseshoe magnet; and the bar-end which always attracts the south pole of the needle is called the north pole of the horseshoe magnet.

The letters **N** and **S** are customarily used to designate the north and south poles respectively of a magnet.

If the compass is placed immediately between the bar-ends of the horseshoe magnet, the needle will take a position straight across between the poles, with the north pole pointing toward the south pole of the horseshoe magnet, and its south pole pointing toward the north pole of the horseshoe magnet.

6. Magnetic Field. — The region throughout which a magnet acts to attract pieces of iron and steel is called the "magnetic field" of the magnet. The magnetic field has its greatest strength near the ends, or poles, of the magnet, and is especially strong in the space between the ends of the horseshoe magnet. The magnetic field is said to be permeated with "magnetic lines of force." The position which a very small compass needle takes when placed in the magnetic field of a relatively large magnet indicates with fair accuracy the direction of the lines of force in the locality occupied by the compass needle. The length of the needle approximately coincides with the direction of the lines of force. The needle must of course be free to swing.

If the north pole of a long, thin magnetic needle is placed between the poles of a horseshoe magnet, the magnetic force tends to move the needle pole in the direction from the north pole of the horseshoe magnet toward the south pole of the horseshoe magnet, which is the direction in which the lines of force act in that locality. If the north pole of the needle is placed in any other part of the magnetic field of the horseshoe magnet, the magnetic force of the latter also tends to move the needle pole in the direction of the lines of force at the needle pole, and to carry it along the same lines of force in the direction from the north pole to the south pole of the horseshoe magnet. The path which the needle pole will follow may be a very indirect one of a circuitous nature.

It is customary to assume that there is a flow of magnetism, called **magnetic flux,** in the magnetic field from the north pole to the south pole of a magnet, the flux at any point being in the direction in which the magnetic force tends to move a magnetic north pole. The complete magnetic circuit through which the flux occurs includes the length of the steel bar from end to end.

7. Magnet Keeper and Its Effect. — A magnet keeper of soft iron or soft (mild) steel is generally provided with a horseshoe magnet. In Fig. 2 such a keeper *A* is shown in place across the ends of the magnet bar. The purpose of the keeper is to prevent the magnet from losing its magnetism.

When the space between the poles of the magnet is bridged by

the keeper as shown in the figure, the magnet will not attract pieces of iron and steel with nearly as much force as when the keeper is not in place. The keeper has a similar effect, and to practically the same extent, if laid against the sides of the bent bar so as to bridge the space between the poles of the magnet. Or the keeper may be made so as to fit between the ends of the bar as shown in Fig. 3, and will then also have the effect of weakening the magnetic field in the manner described.

The weakening of the magnetic field by the keeper is more complete when the keeper fits accurately against the magnet so that there is a large area of metallic contact between them, than when the surfaces that touch each other are rough and make but imperfect contact.

The keeper offers an easier path for the magnetic flux than is offered by air, therefore nearly all of the flux is through the keeper, only a small proportion passing through the air.

The magnetic flux through the bent bar of the magnet is not decreased by bridging the space between the poles with the keeper, but, on the contrary, a large increase of flux through the magnet bar is caused by putting the keeper in place. Proof of the last statement will appear in connection with the method of operating one of the various types of magnetos for generating electricity.

8. Magnetic and Non-magnetic Materials. — Iron and alloys containing a large proportion of iron are the only materials that are magnetic to an appreciable extent. Steel is a combination, or an alloy, of chemically pure iron (ferrum) with other chemical elements.

Except iron and steel, all of the materials ordinarily used in machinery and electrical apparatus are either non-magnetic, or magnetic to only such a slight extent, compared with commercial iron and steel, that they can be considered non-magnetic for the present purpose. These non-magnetic materials include brass, bronze, aluminum, aluminum alloys generally, zinc, porcelain, steatite (soapstone), glass, mica, rubber, pitch, dry wood, wood fiber, cotton, silk, hemp, flax, and paper.

Strictly non-magnetic materials are not attracted by a magnet.

The magnetic field is not affected by their presence. If a piece of non-magnetic material is placed so as to bridge the air gap between the poles of a magnet after the manner of using a magnet keeper, no appreciable change will be produced in the magnetic field.

9. **Compound or Composite Magnets.** — The permanent magnets used in magnetos for generating electricity for ignition purposes are generally made up of several bar magnets bent into the shape of the letter U and grouped closely together. Fig. 4 shows a method of grouping the individual magnets together that is very commonly used for forming a composite magnet. The north poles of all the individual magnets are placed together, and likewise the south poles.

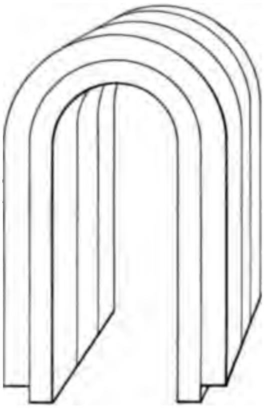


FIG. 4.
Compound or Composite Magnet.

Rectangular bars bent flatwise as shown are very generally used, but other forms of steel bars, including round ones, are also used to some extent. The reason for using composite magnets is that it is difficult, in fact practically impossible, to make magnets of one piece sufficiently large for magnetos to be used for ignition purposes.

Principle of Electric Generators.

10. In all power-driven electric generators the generation of electricity is due to directly and repeatedly varying the number of lines of magnetic force that pass through the opening of a coil of wire (not through the length of the wire itself). This variation generally includes reversing the direction of magnetic flux through the coil opening, although in some unusual designs the magnetic flux is not reversed in direction through the coil opening. Varying the number of lines of magnetism through the coil of wire induces an **electromotive force** in the wire, which tends to cause a flow of electricity through the wire and also

through whatever apparatus may be suitably connected to the wire.

The electromotive force is induced in the coil *only during the time of variation* in the amount of magnetic flux through the coil. A constant flux of magnetism through a coil, without change in the number of lines of magnetic force passing through the coil opening, does not induce an electromotive force in the coil.

The methods by which the number of lines of force passing through a coil are made to vary are numerous. They come under two general methods, however. In one of these general methods the wires of the coil are caused to cut through the lines of magnetic force in such a manner as to vary the number of lines of force passing through the coil. In the other general method the magnetic flux through a bar which the coil encircles is caused to vary in intensity, also generally reverse, without the wires of the coil cutting through any of the lines of force. The more important ways in which the variation of magnetic flux through a coil is accomplished will appear in the descriptions of various types of generators used in connection with electric ignition.

11. The armature of an electric generator consists of a coil, or coils, of wire over or around a core, or cores, of magnetic material which is not a permanent magnet. In the more usual forms of generators for electric purposes, the armature rotates relative to the magnets. In less usual forms, the armature remains stationary with regard to the magnets. In the latter form there is a rotor (rotating part) of soft iron or mild steel, called an **inductor.** In both cases the rotation, or oscillation, of the rotor (armature or inductor) causes a variation in the number of the lines of force passing through the opening of the armature coil, and thus induces an electromotive force in the coil of the armature, so that the coil will deliver current when the electric circuit is properly closed, as through the other apparatus of an ignition system.

CHAPTER II.

LOW-TENSION ALTERNATING-CURRENT MAGNETOS WITH SINGLE-WOUND SHUTTLE ARMATURES.

12. The field-magnets of a magneto are shown in Fig. 5. The field magnet is composite, being made up of six individual magnets in pairs, each pair consisting of a large magnet fitted over a small one.

FIG. 5.
Field-Magnets and Pole-Pieces of a Magneto.

Two **pole-pieces,** or **pole-shoes,** of mild steel or cast-iron, are fastened opposite each other and against the inner surfaces of the inside individual magnets by means of screws which pass through the magnets into threaded holes in the pole-pieces.

The space between the extreme ends of the magnets is bridged by a piece of non-magnetic metal, such as brass or aluminum alloy, which forms a base for the magnetic field and is fastened to the pole-pieces by screws, one of which is shown partly removed beneath the base. The opposite faces of the pole-pieces are bored out cylindrical, so as to fit close to the armature, or inductor, which rotates, or oscillates, between them when the machine is operating. The ends of the pole-pieces are slightly counterbored to receive an end-plate (not shown) and hold it concentric with the bore of the pole-pieces. The use of the end-plate is to support the armature and other parts, as will appear later.

13. Abutted Magnets. — Another arrangement of the field-magnets is shown in Fig. 6. The magnets are placed on opposite sides of the armature space with their ends against each other so that the north poles are together and have one of the pole-

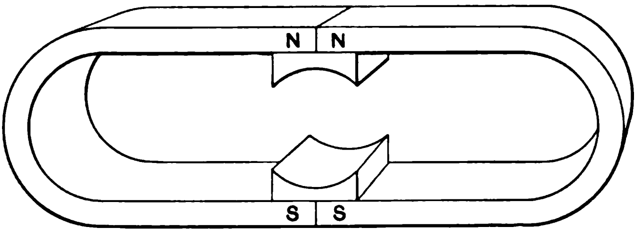


FIG. 6.
Abutted Field-Magnets of a Magneto.

pieces fastened to them. The south poles are also together and have the other pole-piece fastened to them. Composite magnets can be used in this arrangement as well as that shown in the preceding figure.

Rotary Armature Types.

14. An armature suitable for rotating between the pole-pieces of the magnets just described is shown in Fig. 7. The general

FIG. 7.
Armature of an Alternating-current Electric Generator. Shuttle-wound Type.

nature of the construction of the armature can be seen by referring to Figs. 8, 9, and 10.

The core of the armature has the general form shown in Fig. 8. It is made of mild steel or very pure and soft iron machined so that the crowned surfaces have a cylindrical form to fit between the pole-pieces. The crowned surfaces should fit as close as

possible to the pole-pieces without touching them, in order to make the air-gap between the armature and pole-pieces as small as possible.

The **armature winding** is a coil of wire wound around the neck which lies between the crowned sides of the core. Fig. 9 shows the core with part of one layer of winding in place. The neck and sides of the space in which the coil is wound are first cov-

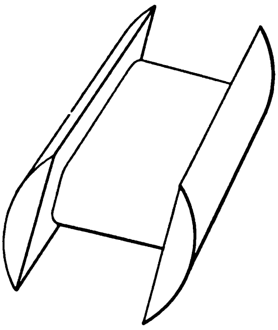


FIG. 8.
Core of Shuttle-wound Armature.

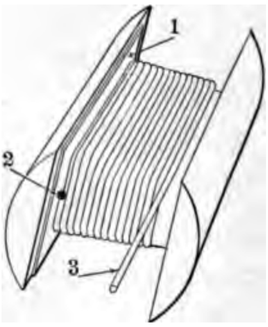


FIG. 9.
Partly Wound Armature of the Shuttle Type.

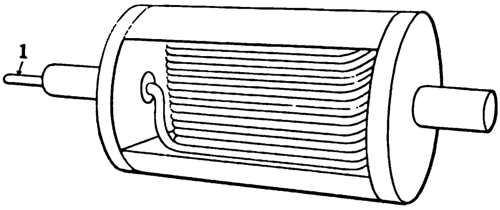


FIG. 10.
Elements of Shuttle-wound Armature.

ered with some insulating material, such as silk or paper that has been oiled or varnished, mica, or wood fiber cut from sheets or molded to form. The insulating material does not allow electricity to flow through it in appreciable quantity. A side piece of insulation is shown at 1 in Fig. 9. Copper wire, covered with cotton or silk thread wound around it so as to form an insulating covering, is used ordinarily. In the better class of work, the wire is covered with two windings of silk or cotton, one winding on top of the other. The wire used in magneto

armatures is commercially known as armature wire or magnet wire, single-covered or double-covered, as the case may be with regard to whether there is one or two layers of thread wound on it.

One end of the wire is bare and fastened to the metal of the armature core at 2, so that the copper of the wire and the metal of the core are in metallic (electric) connection. The rest of the wire is carefully insulated from the core, and the different layers of the coil are also carefully insulated from each other. The wire-end 3 is intended to represent where the wire has been cut off before the first layer of winding was completed, in order to show the nature of the winding.

After the first layer of the winding is complete, the second layer is wound over it, and so on, layer upon layer, till the winding is complete. There is one continuous winding throughout all of the layers. Some insulating material, such as heavy paper or cloth, is generally placed between the layers, especially at the bends of the wire, as a protection to the silk or cotton wrapping of the wire, and to make the insulation more perfect between the layers.

The coil is then wrapped with insulating tape and bound around circumferentially of the core with bare non-magnetic wire, as shown in Fig. 7. The tape is generally of cotton or linen web saturated with insulating varnish. Liquid varnish is also generally applied to the tape while wrapping it over the coil. The varnish is waterproof if the magneto is to be used where there is any likelihood of water reaching it. It is better for it to be waterproof so as to exclude atmospheric moisture even if it is intended to be used only in places free from water. Brass or bronze wire is generally used for the circumferential bands.

A disk-shaped head of non-magnetic material is fastened to each end of the armature core after the winding is completed. Brass, bronze, or aluminum alloy is generally used for these heads. Each head carries a spindle which projects outward from the winding. The spindles are usually made of steel. They run in suitable bearings during the rotation, or oscillation, of the armature while the magneto is operating.

One of the spindles shown in Fig. 10 is hollow. The outer end of the armature wire passes through the hole so that its end projects beyond the spindle at 1. Carrying an end of the armature winding out through a hollow spindle is very commonly used in magnetos intended for ignition purposes, although the wire itself is not generally carried through the spindle. It is more usual to connect the armature wire to a rod or screw which extends through the hole and is insulated from the metal of the spindle either by a tube of hard rubber or vulcanized fiber, a wrapping of sheet mica, or some other suitable means of insulation.

An armature with a core of the shape shown in Fig. 8, and wound as just described, is called either an I-armature, an H-armature, or a shuttle-wound armature. The latter name is on account of the resemblance of the armature in general appearance to the shuttle of a weaving loom. The names I-armature and H-armature come from the resemblance of the core, when looked at endwise, to either the letter I or the letter H, according to whether the core is held, or lies, with the crowned surfaces at the top and bottom, or at the sides.

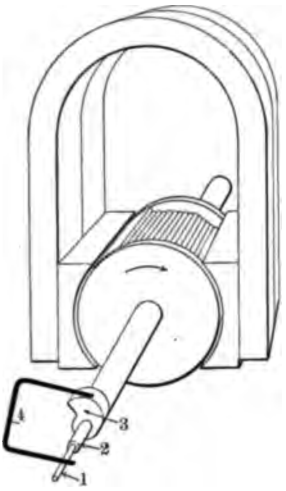


Fig. 11.

Field-Magnets and Armature of Magneto with Device for Showing Positions of Armature for Maximum Electric Arc or Spark.

15. Electric Arc from a Shuttle-wound Armature. — Fig. 11 shows a shuttle-wound armature in place between the pole-pieces of permanent field-magnets. The armature is of the general form of that shown in Figs. 7 and 10. The bare end 1 of the copper wire of the armature winding projects from the end of the hollow spindle, part of the insulation 2 being removed to expose the wire. A cam-shaped projection 3 is shown on the forward end of the front spindle. A cam of this particular form is not usual in commercial magnetos, but is added here to facilitate the explanation of the principle of operation of the magneto.

A bent wire 4 is shown in contact with the bare end 1 of the armature wire and also in contact with the convex surface of the cam or lug 3.

If the armature is rotated in the direction indicated by the arrow on the armature head, and the bent wire 4 is held stationary in the position shown, so as to have rubbing or slipping contact with the wire-end 1 and cam 3, then when the bent wire snaps off the edge of the cam as the latter rotates with the armature, an electric arc will be drawn between the end of the wire and the edge of the cam at the point of separation of the two, provided the speed of rotation is sufficiently high. A rotative speed of 30 to 40 revolutions per minute is sufficient to draw quite a large arc in some magnetos when the parts separate. A magneto of the size commonly used on portable combustion motors will give a large arc when the armature is twirled around through one or two revolutions by grasping the spindle in the fingers; half a revolution caused in this manner will give a good-sized arc in some low-tension magnetos for ignition.

If while the armature is rotating at a speed more or less uniform, the bent wire 4 is swung around to different positions but held so that it is always in contact with both the wire-end 1 and the cam 3 just before the edge of the latter breaks contact with the end of the bent wire, it will be found that while a good-sized arc will be drawn for some positions of the bent wire, at other positions no arc whatever will appear when the contact is broken. After one position of the bent wire for the largest electric arc corresponding to the speed of rotation is determined, it can be seen, by swinging the bent wire slowly around the axis of the rotating spindle, that the other position of the bent wire for maximum arc is diametrically opposite the position first determined. In other words, the largest arc is obtained at two positions of the cam-edge diametrically opposite each other, which may be expressed by saying that the two positions of the cam-edge are half a revolution apart for maximum electric arcs.

The position of the cam at any instant corresponds of course to definite positions of the armature, since the cam and armature are rigidly fastened together.

It can also be seen, by the same process as just described, that the two positions of the bent wire at which no arc is obtained lie midway, or approximately midway, between the positions for maximum arcs. The two positions for no arc are also diametrically opposite each other, and therefore half a revolution apart.

A larger, or hotter, arc is obtained at a high speed of rotation than at slow speed.

16. Effect of Speed of Armature on Position for Maximum Arc. — If the positions of the armature for maximum arc and no arc are first determined as above while the armature is rotating at slow speed, say 50 revolutions per minute, and then the armature speed is increased to say 1200 revolutions per minute, and the experiment repeated, it will be found that the bent wire must be held farther around in the direction of rotation of the armature in the latter case in order to obtain the maximum arc and no arc. This means that the maximum arc occurs later in the revolution of the armature at high speed than at low speed, each revolution being assumed to begin at the same position of the armature, as when the neck of its core is in a vertical position. The cause of this **lag** in the time of production of the maximum arc will be explained later.

17. Positions of Armature for Strong Electric Arc. — The positions of the armature at which the strongest arc can be obtained vary with variation in the forms of the pole-pieces and armature core, as well as with the speed of rotation, as has been mentioned. Most magnetos that are to run at a variable speed when in service are generally so constructed that a strong arc can be produced throughout a considerable range of position of the bent wire applied as stated above. This is done on account of the advance and retard of ignition relative to the position of the pistons of the motor, as well as on account of the lag in the magneto with regard to the position of the armature at the instant of maximum arc. The lag is not so great for the speed usual for combustion motors but that the position of the armature for maximum arc can be pointed out in a general way, as in the following paragraphs.

Fig. 12 shows conventionally the pole-pieces and shuttle-wound

armature of a magneto. A double, or two-lobed, cam is shown fastened to the armature spindle. A bent wire for making electric connection between the cam and the bare projecting end of the armature wire is also shown in place. The two lobes of the cam are diametrically opposite each other and are in such positions relative to the core of the armature that if a line were drawn

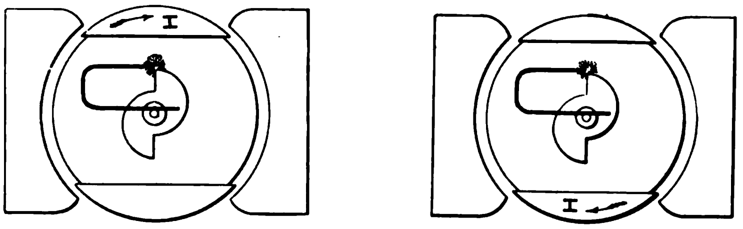


FIG. 12.

Positions of Armature for Maximum Electric Arc or Spark. Approximate.

through the two cam-edges at which the contact with the bent wire is broken as the armature rotates, the line would be parallel to the neck which connects the two crowned parts of the core.

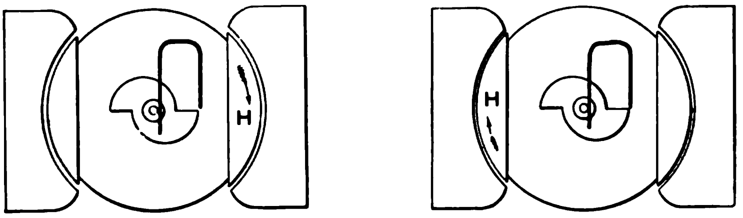


FIG. 13.

Positions of Armature for No Electric Arc or Spark. Approximate.

The bent wire is held so as to break connection with the cam-edge which is uppermost just as the armature core passes through its upright position in which its end view resembles the letter I. The arrow indicating the direction of rotation of the armature may be taken as cut into the metal of the core so that it rotates with the core.

If the armature is rotating at a very slow speed, the maximum electric arc for that speed will be obtained by breaking the circuit while the armature is passing through the vertical positions

shown in Fig. 12, or while it is passing through positions very near the vertical. The maximum spark will occur twice during each revolution.

The positions of no spark are shown in Fig. 13. The neck of the armature core is horizontal, or nearly so, in these positions, so that the end view of the core resembles the letter H.

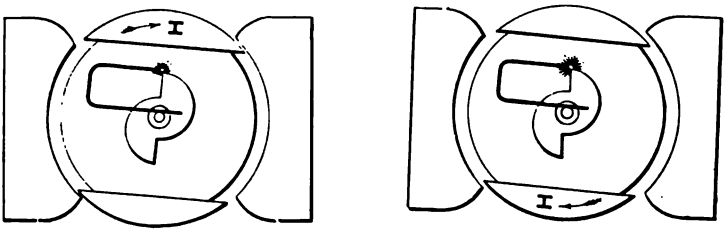


FIG. 14.
Maximum-spark Positions of Armature.

If the armature is rotated at a speed as high as 1200 revolutions per minute, then its positions of maximum arc will be somewhat as indicated in Fig. 14, which positions are somewhat later

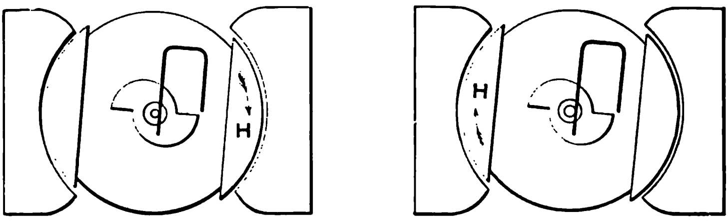


FIG. 15.
Sparkless Positions of Armature.

in the revolution than for slow speed of rotation. The positions of no spark at high speed will be somewhat as shown in Fig. 15.

18. Laminated Armature Core. — The rotation of the armature in the magnetic field induces electric currents, called foucault currents, in the armature, as well as current in the winding of the armature. If the core is made of one solid piece of steel or iron, the foucault currents in it cause it to heat and are otherwise objectionable. In order to keep this objectionable action as small as possible, it is common practice to build up the core

from thin sheet steel cut into I-shaped pieces. The steel used for these pieces is commercially known as armature steel. The pieces are generally cut out by a stamping press.

Fig. 16 shows a laminated armature core built up in this manner. The "disks," or laminations, are sometimes separated from each other by some such material as silk fabric or thin sheet paper properly prepared by oiling or varnishing; in other cases,

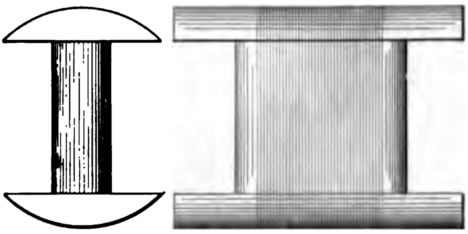


FIG. 16.
Laminated Core of Shuttle Armature.

varnish or the black scale on the surface of the steel is depended on as sufficient insulation. The sheet steel from which the disks are cut is of about the thickness of that used for stovepipes.

The armature disks are pressed together under heavy pressure, as that of a hydraulic press, after they have been grouped to form the core. They are then fastened together by rivets or other suitable means.

19. Magnetic Flux in a Rotating I-shaped Armature Core.— It has been stated that the electromotive force and current in the winding of an armature are induced by changing the amount of magnetic flux through the space surrounded by the coil. In the shuttle-wound armature the variation of magnetic flux occurs in the steel neck of the core on which the insulated wire is wound.

Fig. 17 shows the general nature of the magnetic flux through an I-shaped magnetic core during the time it is rotating between the pole-pieces of the magnets. Only the end views of the core and pole-pieces are shown in the figure. The pole-pieces are marked N and S to indicate the north and south poles respectively. The letter and the feathered arrow indicating the direc-

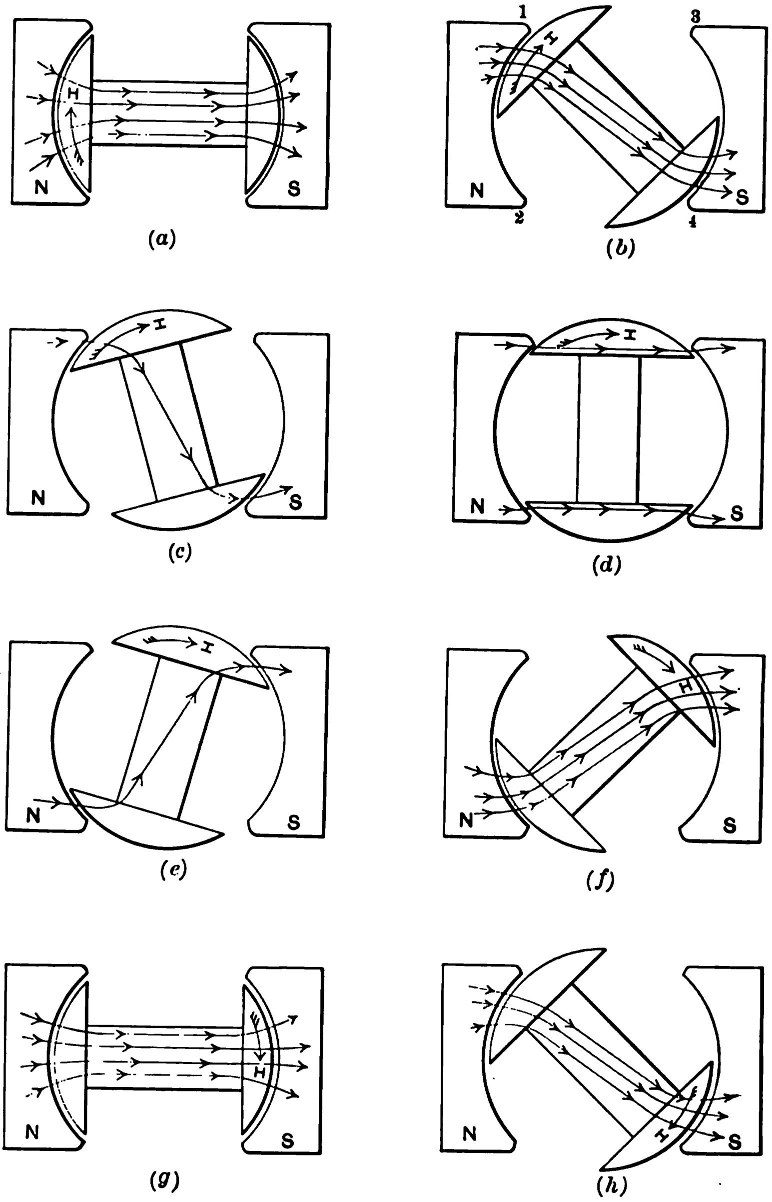


Fig. 17.

Magnetic Flux through Shuttle Armature Core in Different Positions.

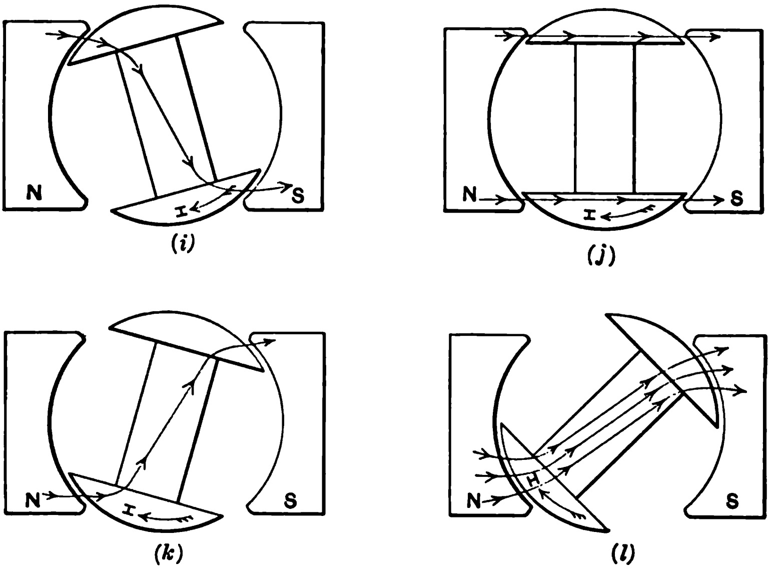


FIG. 17 (*continued*).

Magnetic Flux through Shuttle Armature Core in Different Positions.

tion of rotation of the core may be considered as cut into the metal of the core.

In (*a*) the core is in the H position and the magnetic flux through it is from N to S, as indicated by the lines with arrow heads along them. This is one of the positions of the core in which the greatest amount of magnetic flux occurs through the neck that connects the crowned ends of the core. When the core has been rotated to the position (*b*) there is less flux through it, because less of the crowned ends, or sides, is opposite the pole-pieces. The direction of flux for this position is in general as indicated by the arrow-headed lines. When the core is in position (*c*) there is very little flux through it, because the crowned surfaces have almost entirely moved away from opposite the pole-pieces.

In the vertical position of the core, as shown in (*d*), there is no longer any magnetic flux through the core-neck around which the coil is wound in the complete armature. In other words, the magnetic flux through the coil is of zero value when the core is in the I position. There is some flux through the crowned

ends of the core, however, from pole to pole, as indicated by the arrow-headed lines; but this has no effect to produce electromotive force and current in the armature winding.

In position (*e*) the magnetic flux through the core-neck is in the opposite direction from that in the first three positions, but the flux is from the *N* pole to the *S* pole, as it always is.

In the first three positions the flux is through the core from the arrow-marked side toward the blank side, but in position (*e*) the flux is from the blank side toward the arrow-marked side of the core, as is also the case in positions (*f*) and (*g*). In the latter position the flux is again a maximum of the same value as for position (*a*), but in the opposite direction through the core.

In positions (*g*), (*h*), (*i*), (*k*), and (*l*) the paths of flux are similar respectively to those in (*a*), (*b*), (*c*), (*e*), and (*f*), but the flux is in the opposite direction through the core-neck on account of the core being half a revolution further around in the positions (*h*) to (*l*) than in (*b*) to (*f*). In position (*j*) there is no flux through the core-neck, but the flux through the crowned sides of the core is in the opposite direction from what it was in (*d*), on account of a difference of half a revolution between the two positions.

Fig. 18 is a diagram representing the relative amounts of magnetic flux through the core-neck of an H-armature for all of its positions during one-half a revolution. The distance from *O* vertically up to the curve is the amount of flux when the core is stationary in the position shown in Fig. 17 at (*a*). The vertical distance *B*, Fig. 18, is the flux when the core has been rotated 45 degrees to the position in Fig. 17 at (*b*). At *D*, where the curve crosses the zero line, there is no flux through the core-neck. This corresponds to position (*d*) in Fig. 17. When the armature is in position (*f*), three-quarters of a revolution from the starting position, the flux is equal to that for position (*b*) but in the opposite direction. This is indicated in the diagram by taking the distance *F* below the zero line.

When the core is rotating at a very slow but uniform speed, the *rate of change* in the magnetic flux through the core-neck is more rapid while the core is passing from position (*c*) to position (*e*), and from position (*i*) to position (*k*), than during the other

portions of the revolution. (The reason for limiting this and the following statement to slow speed will appear later.) While the core is passing through positions at and near those shown in (a) and (g), the *rate of change* in magnetic flux through the core is very low compared with the rate for the movements just mentioned. In one position at or near (a), and another at or

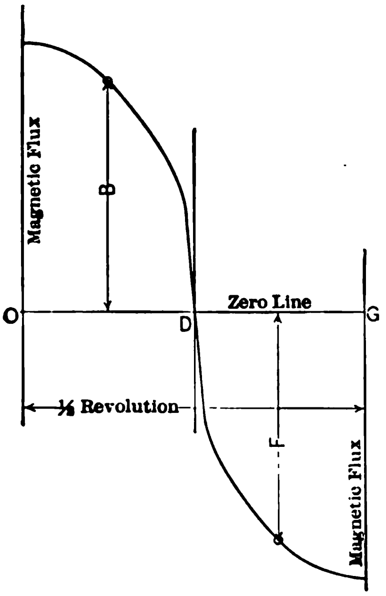


FIG. 18.
Graph Showing Magnetic Flux in Shuttle Armature.

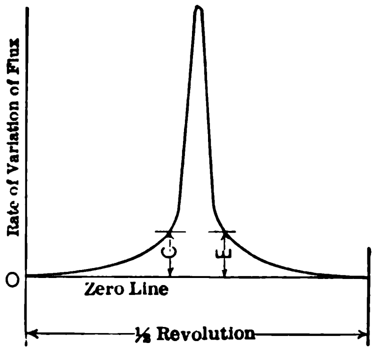


FIG. 19.
Graph Showing Rate of Variation of Magnetic Flux in Shuttle Armature.

near (g), the rate of change falls to zero. This is when the flux stops decreasing and just before it begins increasing.

As the armature core moves from position (c) to position (e), the decrease first occurs in the flux through the core-neck, followed by reversal and increase of flux in the opposite direction through the core-neck. These are together equivalent to a continuous decrease of magnetic flux. The same is true for the movement from position (i) to position (k).*

* This may possibly be more readily understood by considering a somewhat analogous case in the flow of water, as follows: If two pipes are delivering water into a reservoir at the same time, a large pipe at the rate of 50 gallons per minute,

Fig. 19 shows the rate of change of magnetic flux through the core-neck for all positions of the core during one-half a revolution, starting from position (*a*), Fig. 17. The vertical distance *C*, Fig. 19, represents the rate of change of flux while the armature is passing through the position shown at (*c*), Fig. 17. The rate of change for position (*e*) in the latter figure is shown as the vertical distance *E*, Fig. 19. If the curve were given for the second half-revolution, it would be below the zero line, since the increase and decrease take place in opposite directions through the core-neck from what they do in the first half-revolution.

20. Electromotive Force and Current Induced. — If a coil of insulated wire is wound around the core-neck, as in Fig. 20, so as to form an armature, an electromotive force is induced in the coil while the armature is rotating in the magnetic field between the pole-pieces of the magnets. This electromotive force is proportional, or nearly so, to the *rate of change* of the magnetic flux through the core-neck. (A steady flux of magnetism of constant amount does not induce an electromotive force.)

If the electric circuit is closed, a current will flow through the winding whenever there is an electromotive force. In the figure a complete closed electric circuit is obtained by connecting both ends of the insulated wire to the metal of the core. These connections are indicated by black spots and are numbered 1 and 2.

21. Armature Lag. — It has been stated that the maximum arc is obtained later in the revolution of the armature when the speed of rotation is high than when it is low, and that this is due to armature lag.

The armature lag is due to both the magnetic lag of the core

and a small pipe at the rate of 10 gallons per minute, then the rate of increase in the amount of water in the reservoir is $50 + 10 = 60$ gallons per minute. If the flow of the small pipe is stopped and another pipe opened to draw water from the reservoir at the rate of 10 gallons per minute, the rate of increase of water in the reservoir will be reduced to $50 - 10 = 40$ gallons per minute. The difference between the two rates of increase is $60 - 40 = 20$ gallons per minute.

An analogous case is that of first flowing water into a tank at the rate of 10 gallons per minute, then stopping the inflow and drawing out water at the same rate. Drawing out water may be considered as a negative filling of the tank. The difference between the two rates of filling, one positive and the other negative, is $10 + 10 = 20$ gallons per minute.

and the lag of the current behind the induced electromotive force. It requires an appreciable amount of time, in comparison with the speed at which the magneto rotates on a high-speed multi-cylinder motor, to change the rate of magnetic flux in a piece of steel or iron. And the electric current lags slightly behind the electromotive force that is induced by the change of magnetic flux. The current lag is due chiefly to the action of the current in each turn (or single wrap) of the coil winding upon the current in the other turns of the winding, and to the reaction of the current upon the magnetism of the core. These and other causes together produce armature reactance and lag.

Referring to Fig. 17, if (*a*) is one of the two positions of the core for maximum magnetic flux through the core-neck when the core is standing still or rotating at very slow speed, then at high speed of rotation the maximum flux will occur slightly later in the revolution of the core; that is, after the core has passed slightly beyond the position shown in (*a*). And if (*d*) is one of the positions for no flux through the core-neck when the core is not rotating, then the position of no flux through the core-neck will be somewhat further around in the direction of rotation at high speed. Thus, position (*e*) may be the position of no flux through the core-neck at excessively high speed of rotation. The same applies to positions (*g*), (*j*), and (*k*).

The reactions in the armature cause the maximum current to occur somewhat later than the maximum magnetic flux, as has been stated.*

22. Alternating Current Generated. — For convenience in discussing the nature of the current generated in an armature winding, it will first be assumed that there is no lag in the armature.

Referring to Fig. 20, (*A*) is one of the positions of maximum magnetic flux through the core-neck when the armature is standing still, and also when it is rotating, the latter in accordance with the assumed condition of no lag. As the armature rotates

* It is not thought desirable to give any further discussion of armature reactance and lag in a work of this nature, especially as it is very probable that the largest, or hottest, arc is obtained by breaking the electric circuit slightly before the armature reaches the position which would give maximum current if the circuit were left closed.

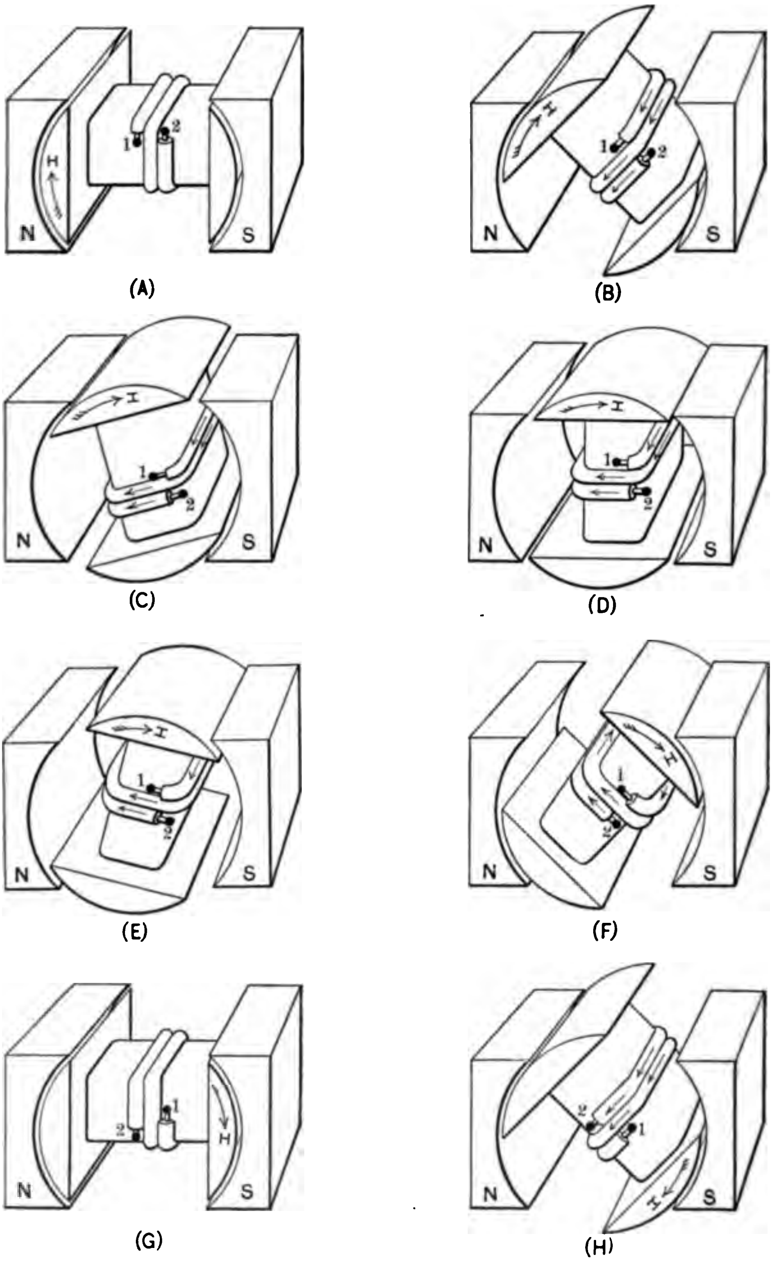


FIG. 20.
Direction of Current Flow in Winding of Shuttle Armature.

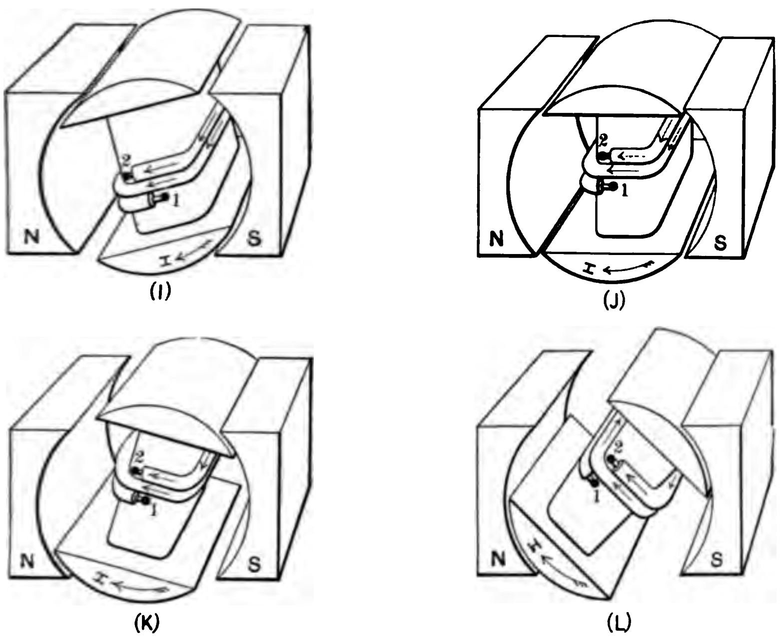


FIG. 20 (*continued*).

Direction of Current Flow in Winding of Shuttle Armature.

through the first quarter-revolution from position (A), the magnetic flux through the core-neck decreases, slowly at first, and at an increasing rate till the armature has reached position (D) at the completion of the quarter-revolution, in which position there is no magnetic flux through the core-neck. The decrease of magnetic flux through the core-neck causes an electric current to flow through the insulated wire of the winding. The direction of flow of the current is as indicated by the arrows on the wire. The path of the current is from 2 through the length of the wire to 1, and thence through the metal of the core from 1 to 2. The current, beginning at zero value, keeps increasing during the first quarter-revolution and reaches its maximum value in position (D). From position (D) to position (G) the current decreases until it drops to zero at the completion of the first half-revolution, corresponding to position (G).

During the second half-revolution, from (G) to (L), a similar

action takes place; but, since the coil has been turned over, the direction of current flow through the wire is opposite that during the first half-revolution. The direction of current flow during the second half-revolution is indicated by the arrows on the wire in (H), (I), (J), and (K). It flows through the wire from 1 to 2.

Briefly, under the assumed condition of no lag, starting from position (A), the current increases from zero to its maximum value during the first quarter-revolution, and decreases to zero during the second quarter-revolution; then increases to a maximum in the opposite direction during the third quarter-revolution, and decreases to zero again during the last quarter-revolution. This action is repeated during each revolution. The speed of rotation has been assumed to be constant.

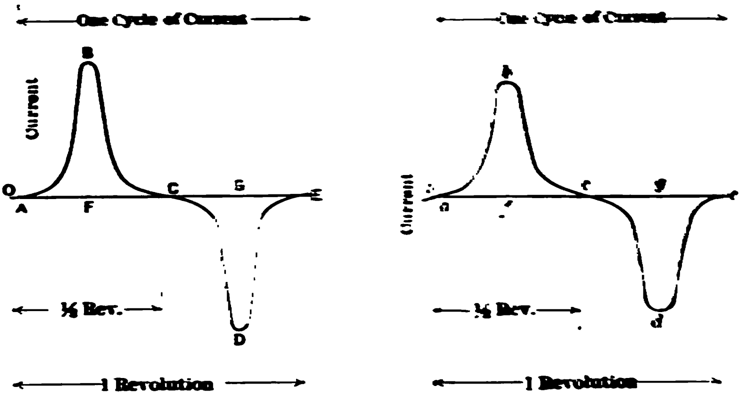
An electric current of the nature just described is called an **alternating current.**

The lag causes the maximum current to occur later in the rotation of the armature than just stated. At a high speed of rotation positions (E) and (K) may be those for maximum current. Although the lag is very small as measured in fractions of a second of time, it may be very appreciable when measured in parts of a revolution of the magneto. Thus, a shuttle-wound magneto that is igniting a six-cylinder four-cycle motor runs at 1800 revolutions per minute when the speed of the motor is 1200 revolutions per minute. The current must rise from zero to its maximum value and drop back to zero again 3600 times per minute, which is 60 times per second. The current has $\frac{1}{60}$ of a second to rise to its maximum and drop back to zero again. A lag of $\frac{1}{1200}$ of a second corresponds to $\frac{1}{40}$ of a revolution, which is 9 degrees of angle.

23. Graphical Representation of Current in a Shuttle-wound Armature. — Fig. 21 shows graphically the general nature of the current generated in a shuttle-wound armature. The revolutions of the armature are measured horizontally, and the amount of current is measured vertically. The rotation is measured from the position in which the magnetic flux through the core-neck is a maximum when the armature is not rotating; this is position (a) in Fig. 17, and position (A) in Fig. 20. In the dia-

gram, Fig. 21, the point of zero rotation is indicated by O. It is assumed that the armature rotates at a uniform speed. The current flow is represented by the curved line $ABCDE$.

The current has zero value at A after the armature has rotated through a small angle. The current increases and reaches its maximum value at B slightly after the completion of the first quarter-revolution. The maximum value of the current at this point is BF. Decrease of current begins at B and continues till zero value is reached again at C, which is half a revolution from A. The flow of current then begins in the opposite direction



FIGS. 21 and 22.
Current in Armature Winding as Affected by Different Forms of Pole-pieces.

and increases till it reaches maximum value again at D, slightly after three-quarters of a revolution. This may be called a negative maximum. Its value is DG. Decrease then begins and the current falls to zero again at E, just after the completion of the revolution.

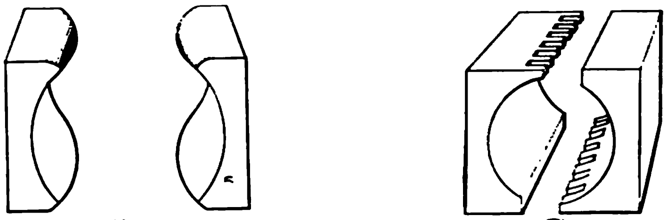
24. Cycle of Current. — The series of changes through which the current repeatedly passes is called the **cycle** of the current. In this case the complete cycle is passed through during one revolution of the armature.

25. Form of Current Curve is Affected by Shape of Pole-Pieces. — The shape of the pole-pieces, especially at the edges,

or lips, determines to some extent the form of the current curve. The lips of the pole-pieces are the edges 1, 2, 3, and 4 in Fig. 17, view (*b*).

If the current curve in Fig. 21 is obtained with the pole-piece lips rounded as in Fig. 17, then for sharp-edged lips like those in Fig. 20 the current curve will be flatter and broader at the top and bottom, somewhat as shown in Fig. 22. The maximum current is not so great in the latter figure, but the current remains large during a greater part of a revolution than in Fig. 21.

Two forms of pole-pieces, which give broad peaks of the nature of those at *b* and *d* in Fig. 22, are shown in Fig. 23. In (A) the



(A) (B)

FIG. 23.

Pole-pieces with Rounded Lips and with Tooth-shaped Lips.

middle portions of the lips extend out farther than the ends. In (B) one lip of each pole-piece is in the form of teeth which resemble, in a measure, those of a comb. The lips with teeth extend out farther from the magnet poles than those which have smooth edges. The pole-pieces in (B) are for an armature that rotates clockwise, so that the surface of the core that is next to the pole-pieces moves away from the pole-piece lips with teeth toward the smooth-lipped pole-pieces. Pole-pieces of the forms of those shown in Fig. 23 give a more gradual rate of change in the magnetic flux as the armature, or inductor, rotates than occurs when the lips are straight as in Fig. 17.

26. Position of Armature for Maximum Arc. — In accordance with what has been stated, it may be seen that in a magneto with a shuttle-wound rotating armature, the largest, or hottest, arc is obtained by breaking the electric circuit while the armature is passing through a position near that in which the crowned

sides of the core span the space between the lips of the pole-pieces, as in Fig. 20 at (*E*) and (*K*).

27. A low-tension alternating-current magneto with shuttle-wound armature is shown in Fig. 24. The illustration is partly a longitudinal section and partly full view, the latter being mostly of interior parts.

The beginning of the armature winding is connected to the armature core by means of a screw so as to make metallic (elec-

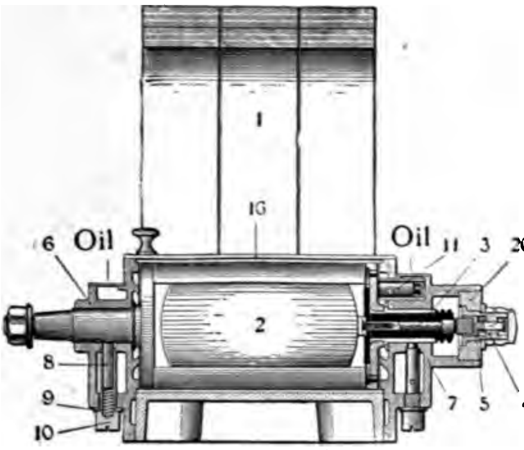


FIG. 24.

Bosch Low-tension Alternating-current Magneto with Rotary Shuttle-wound Armature Mounted on Plain Journal Bearings. Sectional View. Two Sparks per Revolution.

1. Field magnets, composite.
2. Armature plain on journal bearings.
3. Insulated bolt to which one end of armature winding is connected.
4. Terminal with binding nut.
5. Metal mounting for carbon brush which presses against end of 3.
6. Front bearing-plate with plain journal-bearing and felt wick lubricator.
7. Rear bearing-plate with plain journal bearing and felt wick lubricator.
8. Felt wick with coiled spring under it.
9. Leather washer.
10. Wick holder.
11. Carbon brush with coiled spring.
16. Dust cover over armature.
20. Steatite insulating washer on terminal 4.

tric) connection. The end of the winding is metallically connected to the insulated bolt 3 which passes through the hollow rear spindle and projects beyond the end of the spindle. The black around the bolt 3 indicates insulating material. A carbon

brush* mounted in a metallic holder 5 is pressed against the end of the insulated bolt 3 by a coiled compression spring. The three latter parts are carried in an insulated terminal 4, which is provided with a thumb-nut for holding the end of the wire through which current can be carried to other apparatus. A steatite washer 20, to which the terminal 4 is firmly attached, holds the terminal in place and insulates it.

The spindles of the armature are of the plain cylindrical journal type and rotate in corresponding bearings in the plates 6 and 7. The surface of each journal slides over the surface of its supporting bearing.

The carbon brush 11 is pressed against the rear head of the armature by a coiled compression spring so as to make electric connection between the metal of the armature and the body of the magneto.

The path of the current that is generated in the armature winding, assuming a direction of flow, is from the insulated end of the armature winding through the insulated rod 3, carbon brush and mounting 5, terminal 4, wire leading to the external apparatus and through the latter, then back to the body of the magneto, through the brush 11 to the armature head, from which it flows to and through the core to the end of the winding which is connected to the core. The current also passes through the armature winding, of course.

If means, such as brush 11, were not provided for flow of

* In the earlier forms of electric generators, or dynamo-electric machines, a "brush" was a brushlike bundle of copper wires used to make sliding contact between electric conductors for the purpose of allowing current to flow from one to the other. By common usage "brush" has come to mean any form of electric conductor that has sliding contact with another part for the purpose just stated. Ordinarily the brush slides continuously over the part against which it bears. The latter may be either all electric conductor, or it may be part conductor and part insulator. In some cases the electric contact is continuous; in others it is broken by insulation, on which the brush rubs part of the time. Either the brush or the part on which it rubs may be stationary, or both may move so as to have motion relative to each other.

A carbon brush may be made of pulverized charcoal or graphite mixed with suitable binding material and compressed to the desired shape. Frequently fine-woven copper or brass wire (wire gauze) is embedded in the carbon to allow the current to flow more freely through the brush.

current between the armature core and the body of the magneto, the current would have to flow through the journal bearings. This is objectionable, since there is a thin film of oil between the rubbing metal surfaces of the journal and its bearing when they are properly lubricated with oil. Oil is an insulator, and therefore prevents to some extent the flow of current even when the film is as thin as in bearings of this sort. The electric resistance of the oil film also causes heating of the rubbing surfaces and

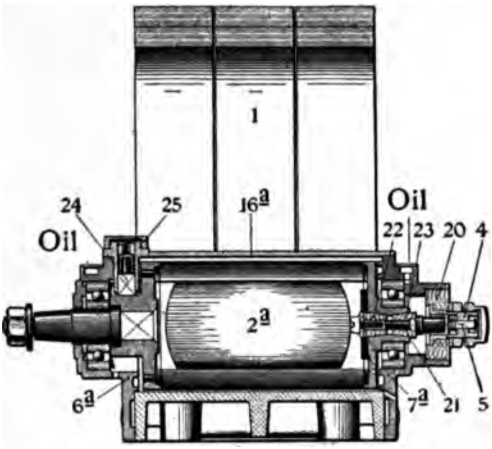


FIG. 25.

Bosch Low-tension Alternating-current Magneto with Rotary Shuttle-wound Armature Mounted on Ball Bearings. Sectional View. Two Sparks per Revolution.

1. Field magnets, composite.
2a. Armature on ball bearing.
4. Terminal with binding nut.
5. Metal mounting for carbon brush which presses against end of 21.
6a. Front end-plate for ball race.
7a. Rear end-plate for ball race.
16a. Dust cover over armature.
20. Steatite insulating washer on terminal 4.
21. Insulated bolt to which one end of armature winding is connected.
22. Inside steatite insulator on armature.
23. Outside steatite insulator on armature.
24. Carbon brush with mounting and coiled spring.
25. Screw cover.

tends to burn the oil, thus injuring the effectiveness of lubrication. All of this is objectionable.

The journal bearings are each lubricated by means of a pencil-shaped felt wick, one of which is shown at 8. It is pressed up

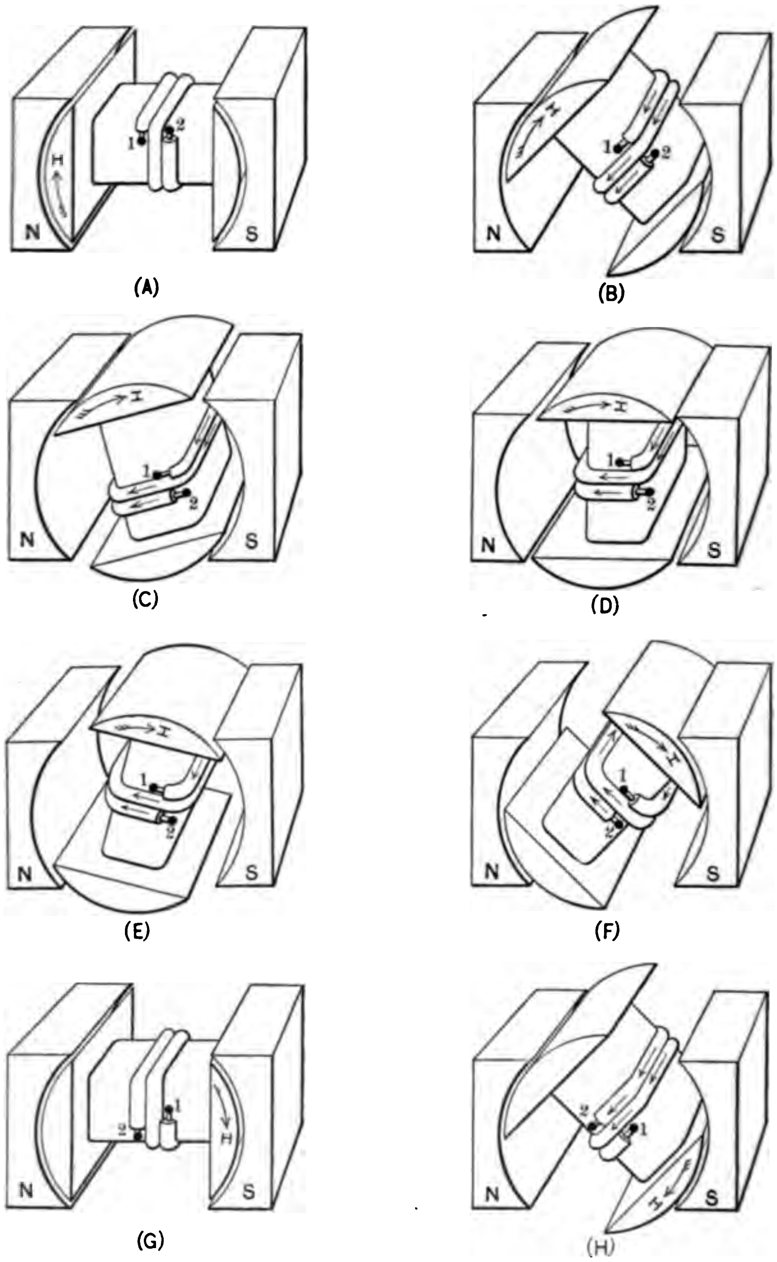


FIG. 20.
Direction of Current Flow in Winding of Shuttle Armature.

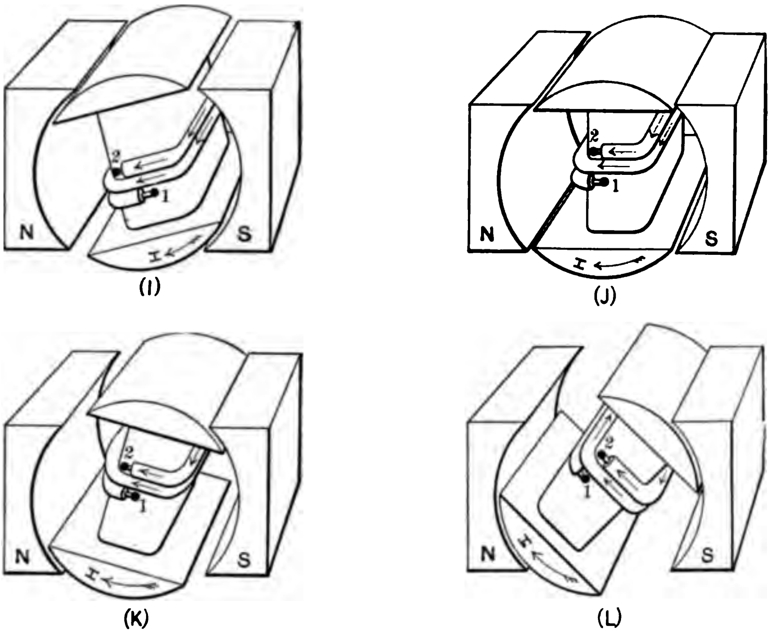


Fig. 20 (*continued*).

Direction of Current Flow in Winding of Shuttle Armature.

through the first quarter-revolution from position (A), the magnetic flux through the core-neck decreases, slowly at first, and at an increasing rate till the armature has reached position (D) at the completion of the quarter-revolution, in which position there is no magnetic flux through the core-neck. The decrease of magnetic flux through the core-neck causes an electric current to flow through the insulated wire of the winding. The direction of flow of the current is as indicated by the arrows on the wire. The path of the current is from 2 through the length of the wire to 1, and thence through the metal of the core from 1 to 2. The current, beginning at zero value, keeps increasing during the first quarter-revolution and reaches its maximum value in position (D). From position (D) to position (G) the current decreases until it drops to zero at the completion of the first half-revolution, corresponding to position (G).

During the second half-revolution, from (G) to (L), a similar

cut from a tube by slotting it lengthwise. They are of mild steel as already stated, and are held together by disk-shaped heads

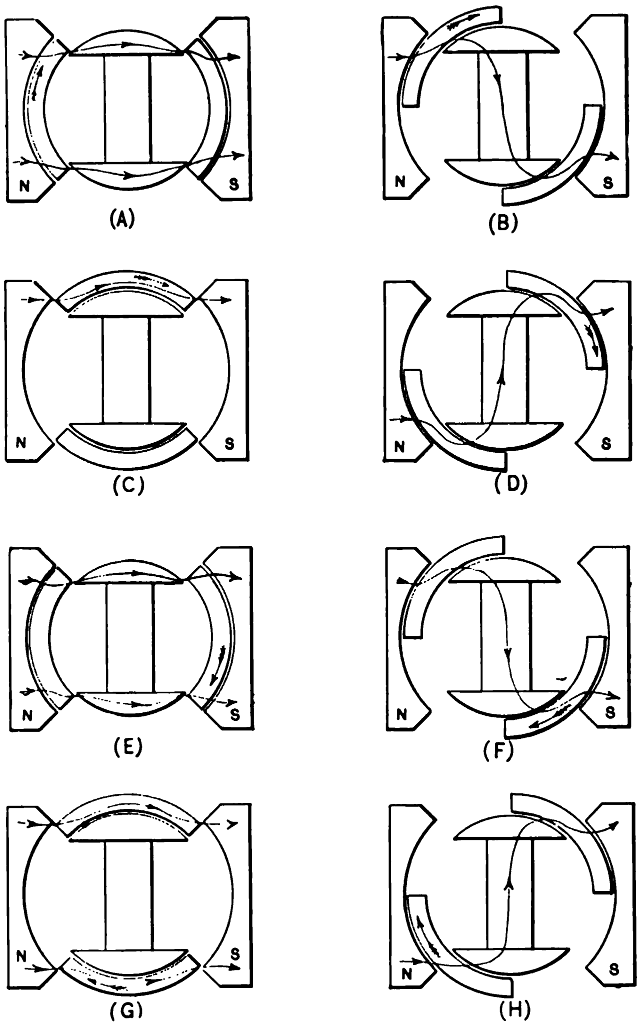


FIG. 30.

Magnetic Flux through Stationary Armature Core and Rotary Sleeve.

of non-magnetic material, such as brass, bronze, or aluminum alloy, attached to them by suitable fastenings (screws in this case). One of the heads has a driving spindle.

29. The action of the magnetic sleeve in causing a variation of magnetic flux through the core-neck of the armature can be understood by reference to Fig. 30, in which the sleeve is shown in all of its positions for maximum magnetic flux and for no flux through the core-neck, no allowance being made for armature lag. The direction of rotation of the sleeve is indicated by the feathered arrow, which may be taken as stamped on the end of the sleeve. The general direction of magnetic flux is indicated by the lines with arrowheads along them.

In (A) there is no magnetic flux through the core-neck, but a slight amount occurs through the crowned sides of the core. In (B) the flux has a maximum value through the core-neck from top to bottom; this position is about one-eighth of a revolution later than (A). In (C) the sleeve bridges the gap between the pole-pieces, and there is no flux through the core-neck. In (D) the flux again has a maximum value through the core-neck, from bottom to top, which is in the opposite direction from the flux in (B). In (E) there is no flux through the core-neck. This completes the first half-revolution, starting from position (A). It may be noted that the flux, and consequently the current, reaches maximum value twice during half a revolution, and since the flux is in opposite directions in (B) and (D), the current flows in opposite directions in these two cases. An alternating current is therefore generated.

During the latter half of the revolution the variation of flux through the core-neck is the same as that during the first half-revolution. The current therefore passes through two complete cycles during one revolution. An arc can be drawn four times per revolution by breaking the circuit at or about the time maximum current occurs.

The field-magnets and pole-pieces for a magneto with a stationary shuttle-wound armature and rotary magnetic sleeve can be of the same form as those for a rotary shuttle armature.

30. Note. — There are several types of magnetos designed especially to deliver low-tension alternating current for use in high-tension ignition systems. The more important of these will be described in connection with high-tension ignition.

CHAPTER III.

DIRECT-CURRENT MAGNETOS.

31. General. — By the use of a suitable form of armature between the pole-pieces of permanent magnets, a direct current can be obtained. The same magnets and pole-pieces can be used as for the shuttle-wound armature, but the armature core

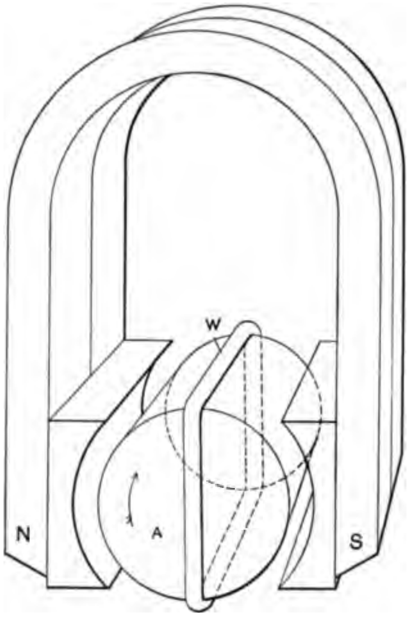


FIG. 31.
Elementary Form of Drum Armature between Pole-Pieces of Magnets.

is different. Several forms of cores are used, among which one in the form of a cylinder, and another having the form of a ring, are most common. The cylinder generally has lengthwise slots to receive the winding. An armature with a cylindrical core is

generally known as a drum armature. This applies whether the core has a smooth cylindrical surface or is slotted as just stated.

32. Elementary Form of Drum Armature. — A cylindrical core A with one turn of insulated wire W around it is shown in Fig. 31 in the magnetic field between the pole-pieces of a set of permanent magnets. The wire is continuous (without ends). The magnetic flux is from the N pole across the air-gap between the N pole and the core to the core, through the core and across the air-gap between the core and the S pole to the latter. The same number of lines of magnetic force pass through the smooth cylindrical core whatever its position with regard to rotation about its axis. This is also approximately true of a slotted cylindrical core of the usual form.

33. Generation of Current. — When this elementary armature is standing in the position shown in Fig. 31, all of the magnetic lines of force in the core pass through the space inclosed by the wire. Other positions of the armature are shown in Fig. 32. When in position (A) part of the magnetic flux through the core passes through the space inclosed by the loop of wire, and part passes outside of the loop. In (B) none of the flux is through the space inclosed by the loop. In (C) part of the flux in the core is through the coil space, and in (D), half a revolution from the position in Fig. 31, all of the flux through the core passes through the coil. The direction of the flux through the coil space is in the opposite direction in (D), relative to the coil, from its direction in Fig. 31, where it enters the coil space from the side next to the feathered arrow cut into the core. In (D) the flux enters the coil space from the side opposite the feathered arrow, which rotates with the core and coil.

When the armature is rotating, the positions at which all of the flux in the core passes through the coil, and those at which none of the flux passes through the coil, occur later in the revo- ... account of magnetic lag and the reactions which occur ... the electric current generated in the coil and other

... cussing the manner in which a direct

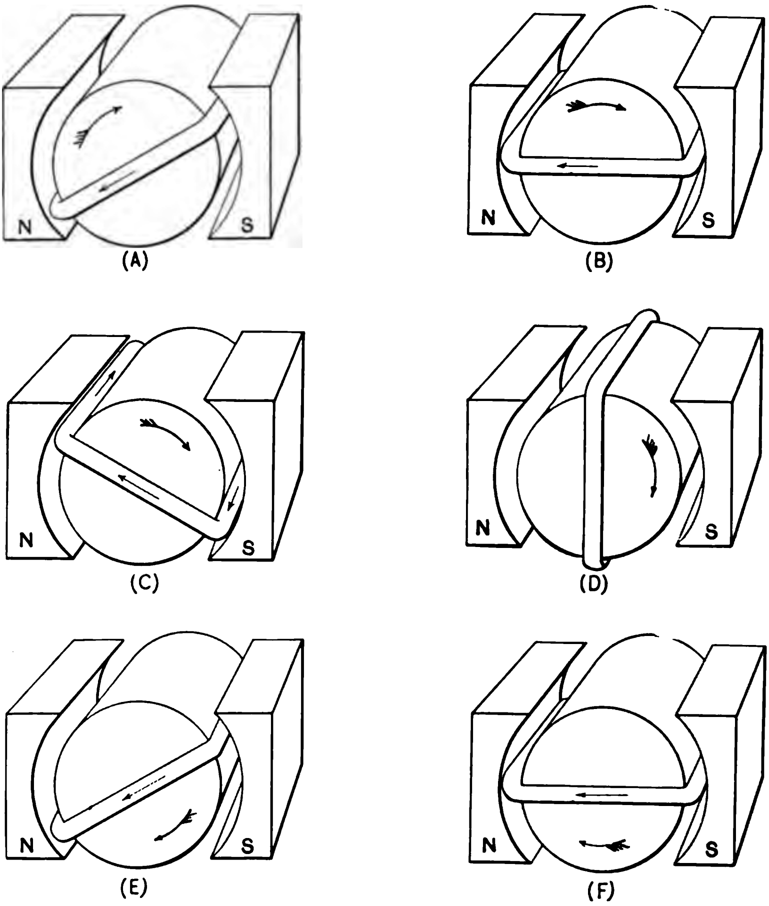


Fig. 32.

Current Flow in Winding of Elementary Drum Armature.

current is obtained, the effect of magnetic lag and armature reactions will be neglected.*

As the armature passes through the position shown in Fig. 32 at (*A*) while rotating in the direction indicated by the feathered arrow, electromotive force is generated in the wire of the coil and current flows through the wire in the direction indicated by

* It is not thought necessary to discuss more fully the effect of cross-magnetization and armature reactions.

the arrow on the wire. The direction of current flow is similarly indicated in (*B*), (*C*), (*E*), and (*F*). There is no current flow in position (*D*) and in the position shown in Fig. 31. The electromotive force at any instant is proportional to the rate at which the stretches of wire along the cylindrical surface of the core are cutting through the lines of force. This rate corresponds to the rate of change in the amount of magnetic flux through the space inclosed by the coil. The current is approximately proportional to the electromotive force at any instant. In the positions shown in Fig. 31, and at (*D*) in Fig. 32, the wire is not cutting through lines of magnetic force, hence there is neither electromotive force nor current.

In (*E*) and (*F*) the direction of current flow through the wire is opposite that in (*A*), (*B*), and (*C*). In (*E*) and (*F*) the arrow indicating the direction of flow through the stretch of wire across the front end of the core points in the same direction as the feathered arrow engraved in the end of the core, while in positions (*A*), (*B*), and (*C*) the arrows point in opposite directions. The reason why the current changes its direction of flow has been discussed in § 22. It should be noted that the direction of current flow through the portion of the wire that lies across the end of the armature core is always from the *S* pole toward the *N* pole when the armature is rotating clockwise. In other words, the current flow through the wire next to the south pole is always toward the observer when the rotation is clockwise.*

34. Commutation of Current in a Direct-current Generator. — In Fig. 33 the coil of wire is cut in two at the front end and the ends fastened to two parts, 1 and 2, which are approximately half-rings of metal. Brushes, 3 and 4, of metal, carbon, or some other conductor of electricity, bear on the rings at points (really areas) diametrically opposite each other. From these brushes wires connect to an external circuit 5. While the armature is rotating clockwise through the position shown, the current flows from brush 3 (next to the *S* pole) to the external circuit 5, through the external circuit and then to the brush 4. This continues as

* If the rotation were in the opposite direction, the current flow would also always be in the opposite direction from that indicated.

long as brush 3 is in contact with segment 1 and while current is generated in the armature coil. When the armature reaches a position similar to that in Fig. 31, which may be called the "dead" position of the coil, the open spaces between the two segments have come under the brushes. The brushes therefore change from one segment to the other of the ring while no current is flowing, and consequently there is no spark formed during this

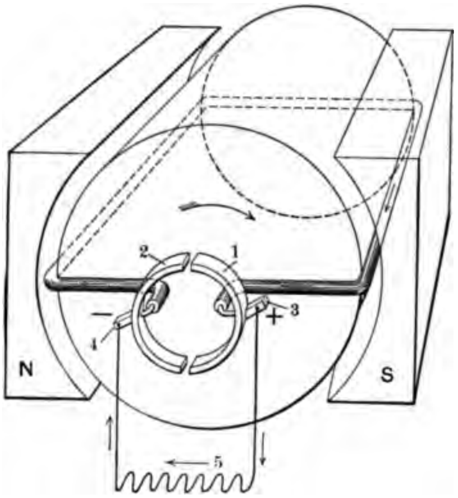


FIG. 33.

Two-segment Commutator and Brushes of Elementary Drum Armature.

change from one segment to the other. When segment 2 is alone in contact with brush 3 and current is again generated, the flow is, as before, from brush 3 through the external circuit 5 to brush 4. By the use of this two-segment commutator the flow of current through the external circuit is caused to be always in the same direction. The flow of current in the armature wire alternates as before, however.

Since the flow of current is always from brush 3 to the external circuit, this brush is called the *positive* brush and is usually indicated by the sign +. The other brush, 4, toward which the current flows, is indicated by the sign −, and is called the *negative* brush.

A current which flows in one direction only is called a ***direct current***. As produced by the elementary generator shown in Fig. 33, it is intermittent, or, more specifically, ***pulsating***.

35. Continuous-current Electric Generator. — In order to obtain a continuous current it is necessary to use more than one armature coil and more than two commutator segments. To operate successfully for the usual requirements, the coils are spaced uniformly around the core, and the commutator segments are all of the same width circumferentially. In the more usual constructions there is the same number of commutator segments as there are coils, but not infrequently twice as many commutator segments as coils are used. Each coil may have only one turn, as in Fig. 33, or each may have several turns, or wraps. It is probably that in all direct-current generators intended for ignition purposes, each armature coil has several turns.

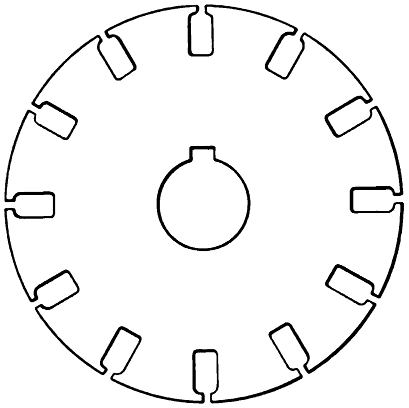


FIG. 34.

Thin Disk of a Laminated and Slotted Drum Armature.

36. Laminated Drum Armature Core. — In the better generators for direct current the armature core is built up of a number of thin disks cut from sheet metal and placed side by side in the same manner as has been described for shuttle-wound armatures and for the same reason. One of the disks for a direct-current generator is shown in Fig. 34. The metal is cut out at regular

intervals around the periphery to leave openings which, when the disks are grouped together in the armature, form the slots in which the wire is wound. The central opening is for the armature spindle, which is usually all in one piece and passes through the core. It is good practice to place a brass sleeve, or quill, between the steel spindle and the core-disks.

37. A complete drum armature for direct current is shown in Fig. 35. This armature has 12 coils, each of several turns of

Fig. 35.
Drum Armature of Direct-current Electric Generator.

wire wound in the slots of the core, and 12 segments in the commutator.

38. A commutator similar in general form to that on the armature in the preceding figure is shown in Fig. 36, in which (*A*) is a

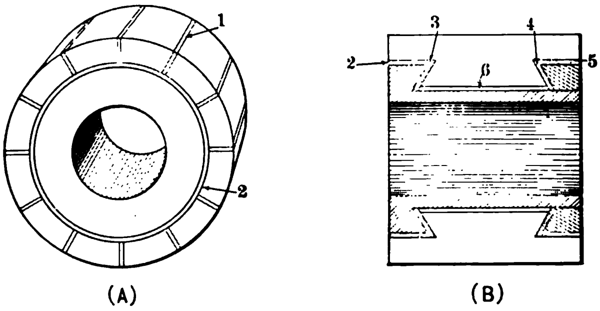


Fig. 36.
Commutator for Direct-current Electric Generator. Twelve Segments.

view of the complete commutator, and (*B*) is a longitudinal section. The segments are dove-tailed and held in place by the

correspondingly dove-tailed inner sleeve and ring. Insulation 1 is placed between the adjacent copper segments, and at 2, 3, 4, and 5 between the segments and the metal sleeve. The annular space 6 may or may not have insulation in it, according to the will of the designer. There is a possibility of moisture collecting in this space if it is not filled with insulation. The insulation between adjacent segments must be of some material that will withstand heat and is not readily burned by the sparks that form as the brushes pass from one segment to the next, especially when the brushes are not properly set. Mica or some composition composed chiefly of mica is used for this insulation.

Various methods of fastening the ends of the armature coils to the segments are used. A common one is to notch or slit the end of the segment and solder the wire into the notch. A hard solder (one that does not melt at a low temperature) should be used, so that it will not melt and fly out in case the commutator becomes hot. It is well to swedge the segment down on the wire to prevent the latter from flying out in case the solder melts. Screws are sometimes used to fasten the wire to the segments, but they are apt to become loose, unless soldered, on account of the expansion and contraction due to heating while in service and cooling while at rest.

39. Armature Connections. — Fig. 37 is a diagram showing conventionally how the ends of the armature coils are brought to the segments of the commutator. This diagram is for an armature with 12 coils and the same number of commutator segments, intended for use in a bipolar generator. Only one turn of wire for each coil is represented, but each coil may have several turns.

Starting at segment 1, connection is made to one side A of a coil lying in a slot of the core. Side A is connected, across the back end of the core, to the side A' of the same coil, and A' is connected to the segment 2. Segment 2 is also connected to B, which is connected across the back end of the core to B', and the latter is connected to segment 3. The same method of connection is followed out for all of the coils, thus: 3, C, C', 4; 4, D, D', 5; and so on to 12, L, L', 1.

The coils are not shown connected in the successive order in

which they have to be wound on the core. The successive order of winding is *A*, *H*, *C*, *J*, *E*, *L*, *G*, *B*, *I*, *D*, *K*, *F*. If the coils were connected to the commutator in the order of their winding, as just given, the lengths of the different circuits through the

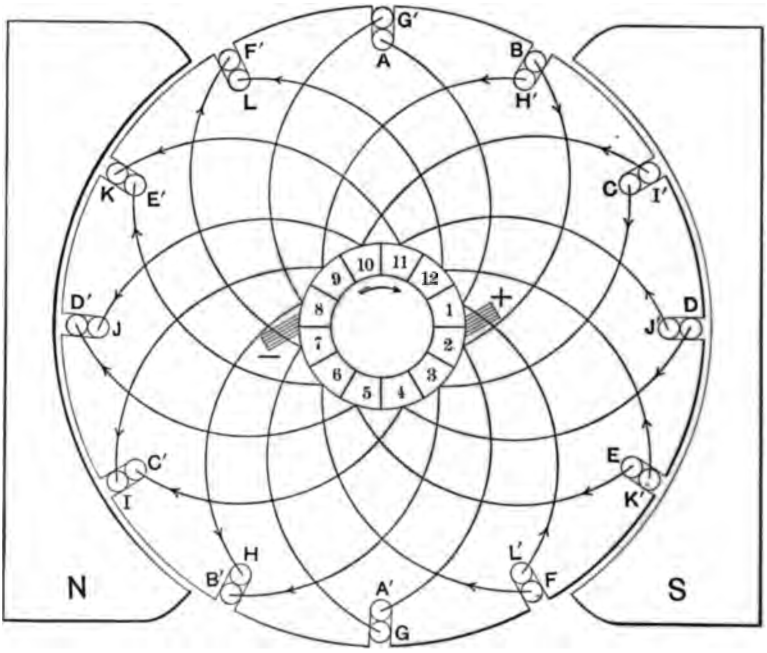


FIG. 37.

Winding Diagram of Direct-current Armature with Twelve Coils and Twelve Commutator Segments.

armature would not be uniform, and the armature would not operate as satisfactorily as when the connections are made as has been shown.

The direction of current flow through the connections to the commutator is indicated by the arrowheads on the lines representing the connections.

The brushes are shown in contact with the commutator, and are indicated as positive and negative by the signs + and –. It can be seen that the + brush electrically connects the segments 1 and 2, to which the ends of the coil *A* are attached, when

the armature is in the position of its rotation shown in the diagram. The brush bridges the insulation between 1 and 2. This corresponds to the connection that occurs between the two half-

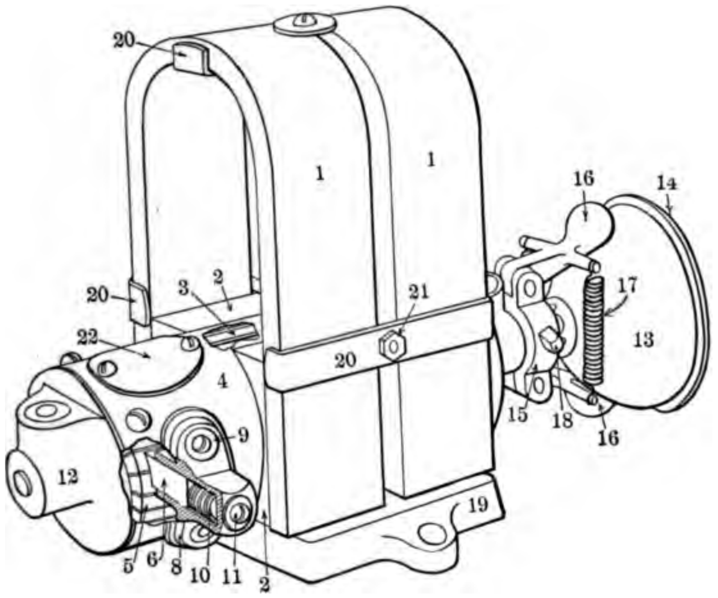


FIG. 38.

Direct-current Magneto. Hercules Electric Co., Indianapolis, Ind.

1. Field magnets.
2. Pole-pieces.
3. Armature.
4. Brass tube enclosing armature.
5. Commutator.
6. Brush that bears on commutator.
7. Brush-holder. Insulated.
8. Insulation between brush-holder and tube 4.
9. Insulation around screw that holds brush-holder in place.
10. Coil-spring for pressing brush 6 against commutator.
11. Terminal for external wire.
12. Bearing for armature spindle.
13. Bell-shaped friction pulley.
14. Friction facing of pulley 13.
15. Collar for speed governor.
16. Governor balls and arms.
17. Governor spring.
18. Setscrew.
19. Base of magneto.
20. Clamps for holding magnets against pole-pieces.
21. Clamp bolt.
22. Name plate.

rings in Fig. 33 when the armature in the latter figure has rotated one-quarter revolution from the position shown. But in Fig. 37 the coil *A* is in its dead position when thus short-circuited by

the brush, just as the coil is in Fig. 33 when the ends of the half-rings are under the brushes, therefore no electromotive force is induced in the coil to cause current flow in that coil which would cause sparking at the brush when segment 2 passes from contact with the brush and thus breaks the short-circuit of coil *A*. The same applies to coil *G*, which is shown short-circuited by the negative (−) brush. It also applies to all the other coils as their segments pass successively under the brushes.

40. A complete direct-current magneto for giving a continuous current is shown in Fig. 38. The armature is surrounded by a brass tube 4 through which the pole-pieces project so as to come

FIG. 39.
Photographic View of Direct-current Magneto shown in Fig. 38.

close to the armature. This tube, together with the heads which carry the spindle bearings, form a dust- and water-proof protection for the armature. The brushes are made of phosphor-bronze wire gauze pressed in dies to a suitable form around a carbon core. The carbon acts as a lubricator for the rubbing surfaces of the brushes and commutator. A bell-shaped friction pulley 13 is carried on the driving end of the armature spindle. This pulley is faced with a suitable friction material, such as leather, paper composition, or rawhide, which is pressed by spring action axially against a rotating part, such as a flywheel or pulley that drives the friction pulley. The speed of rotation of the armature is controlled by a shaft governor of the fly-ball type. The balls

are drawn toward each other radially by a pair of coiled tension springs, one of which, 17, is shown. As the speed increases the balls move out radially and reduce the pressure between the

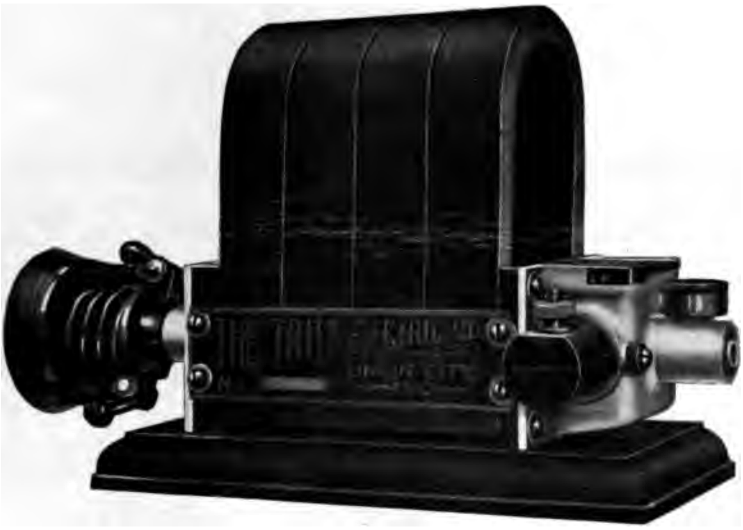


FIG. 40.
Direct-current Magneto with Friction Pulley and Speed Governor. Tritt Electric Company, Union City, Indiana.

facing of the friction pulley and the flywheel. This action allows the friction pulley to slip enough on the flywheel to keep the speed of the armature down to the required rate.

Fig. 39 is a photographic view of a direct-current magneto of the general type shown in the preceding figure. Fig. 40 illustrates another machine that operates in a similar manner.

CHAPTER IV.

TESTING FOR DIRECTION OF CURRENT.

Chemical Tests.

41. Water Test. Bubbles Form at Submerged Wire-End. — To about half a pint of water in a glass tumbler or other vessel that is not a conductor of electricity add any one of the following:

Common salt ($NaCl$), one teaspoonful;

Common washing soda (sal soda, Na_2CO_3), one teaspoonful;

Sulphuric acid (H_2SO_4), half teaspoonful of the strength sold at drug stores;

Hydrochloric acid (HCl), half teaspoonful of the strength sold at drug stores.

Connect a small wire with each of the two brushes of a direct-current generator, or with the positive and negative terminals of any source of direct-current supply, and dip the free bare-metal ends of the wires into the impure water, first keeping the ends as far apart as possible and then gradually bringing them toward each other, without allowing them to touch.

Bubbles of gas will form on and rise from the submerged end of the wire that is connected to the negative (−) side of the source of direct-current supply. (This test does not apply to alternating current.) With the small currents and pressures commonly used for ignition purposes, there is no appreciable formation of bubbles at the positive wire-end.

There are numerous other substances that can be used for adding to the water to make it impure for the direction-of-current test. In fact, water from city mains often contains enough matter in solution to make it impure enough (chemically speaking) for this test.

The passage of the direct current through the impure water decomposes it into its chemical elements, hydrogen and oxygen, each of which is a gas. This action is more or less indirect so

far as the water itself is concerned. The hydrogen is liberated at the negative terminal. When water is decomposed it gives two volumes of hydrogen for each volume of oxygen. The oxygen tends to collect at the positive terminal, but at least part of it is absorbed by the water and thus disappears so far as its being a gas is concerned.

Each of the submerged ends of the wire is called an **electrode.** The liquid, in this case impure water, is called the **electrolyte.** The positive electrode (the one connected to the positive side of current supply) is called the **anode,** and the negative electrode is called the **cathode.**

The decomposition of the water sets up a counter-electromotive force of about 1.48 volts. This is about the maximum electromotive force of one cell of ordinary dry electric batteries such as are in common use for ignition. One cell of such a battery will not therefore generally give bubbles at the electrode in this test. At least two cells must be connected in series to make certain of producing bubbles. Different methods of connecting cells to form a battery are given later.

42. Color Test. — If a tablespoonful of sal ammoniac (ammonium chloride, NH_4Cl) is dissolved in half a pint of water, and the bare ends of two wires placed in the liquid as described in the preceding article, the liquid around the positive terminal, or anode, will turn blue, and bubbles will form at the negative terminal, when current flows.

There are several substances that will give color tests of this nature. Different colors are obtained according to the substances used.

Convenient devices for making color tests are found on the market. A small glass tube some two inches in length, set in a mounting and having suitable terminals, is a convenient form. The instrument should be marked so that there can be no mistake in determining which of the two wires connected to it to test them is positive or negative.

Test with Magnetic Needle.

43. Magnetic-compass Test. — Place the wire which carries the current immediately above the case in which the magnetic needle is mounted, as in Fig. 41, so that the direction of the wire is the same in general as the length of the magnetic needle. If the wire is not insulated it is best not to let it touch the metal of the case. It is immaterial whether it touches the glass. The

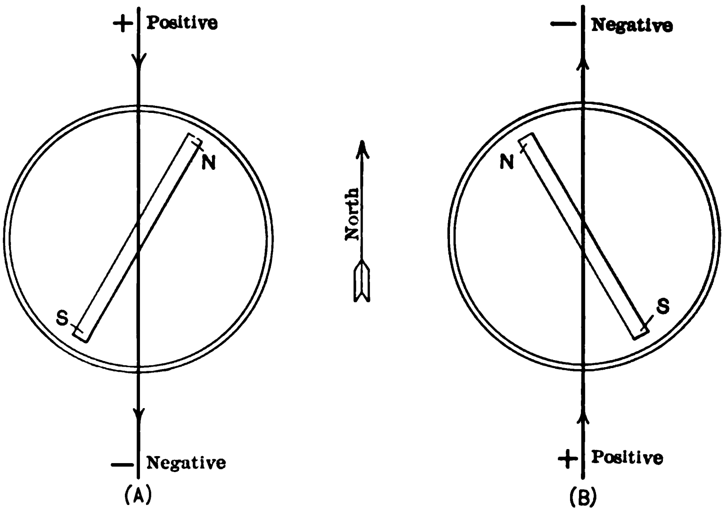


Fig. 41.

Magnetic Compass Indicating Direction of Flow of Electric Current by the Deflection of the Needle.

needle will be deflected from its north-and-south position during the time a direct current flows through the wire placed in this position.

If the current flows from the north toward the south above the needle, it will be deflected in a clockwise direction as indicated at (*A*). In other words, the needle will be turned through part of a revolution in the same direction that the hands of a clock rotate.

A current from the north above the needle turns it clockwise is a convenient expression by which to remember the action of a direct current on a magnetic needle.

If the current flows in the opposite direction (toward the north) above the needle, it will be rotated in the opposite direction as shown in (B). By placing the wire beneath the needle, the action on the needle will be the reverse of that when the wire is above the needle.

44. Extemporized Compass Needle. — An ordinary sewing needle magnetized and floated on water in a non-magnetic vessel can be conveniently used in the absence of a compass. The needle can be magnetized by bringing it in contact with a magnet, or by means of an electric current. The latter method is explained in Chapter VI.

If the sewing needle is highly polished, as when new, it can be floated on water by first drying it and then rubbing it with a slightly oily cloth or one's fingers, slightly oily. If then laid, or dropped lightly, on the water it will float and quickly assume a north-and-south direction. A needle that is bright and properly oiled will float a day or more. The action of the electric current upon this floating needle is the same as on the pivotally supported needle in a compass.

Another method of floating the needle is to lay it on, or stick it through, a flat piece of cork or paraffin.

A cup or saucer is convenient for holding the water. A brass, copper, or aluminum vessel will answer, but the wire, if bare of insulation, should not be allowed to touch the vessel in two places at the same time. A steel or iron vessel is not so satisfactory on account of the tendency of the needle to float up against the side.

45. Test with Measuring Instruments. — Many of the ammeters and voltmeters for measuring current and pressure are made so that the direction of the current flowing through them can be told. The terminals of the instrument are marked + and −, or $P+$ and $N-$. The indicating needle, or pointer, of the instrument moves so as to give a reading on the graduated scale only when the wires are connected to the instrument terminals in accordance with the signs; the positive wire to the terminal with the + sign, and the negative wire to the terminal with the − sign.

CHAPTER V.

ELECTRIC MEASURING INSTRUMENTS.*

46. General. — It is often desirable to test a battery to determine its condition by measuring its voltage and the amount of current that it will give; also to measure the amount of current that an ignition system is using. For this purpose numerous types of small portable instruments have been developed, and a lesser number of instruments intended to be fixed in place. The smaller portable instruments frequently resemble a watch or pocket compass in general appearance, and are about the size of a large watch. These instruments ordinarily operate on the principle that an electric current flowing through a coil of wire attracts or repels a permanent magnet or a piece of magnetic material and causes it to move when it is mounted so as to allow movement, or upon the principle that two coils of wire with current flowing through them attract or repel each other so that one coil is moved when mounted for such movement.

FIG. 42.
Portable Ammeter for Measuring Electric Current. Small Pocket Form.

The chief difference between the ammeter, for measuring current, and the voltmeter, for measuring pressure, is that the ammeter has a coil, or coils, of comparatively thick wire of short length which has a very low resistance, and the voltmeter has a coil, or coils, of very thin wire of great length and very high resistance.

47. Ammeters. — A small portable ammeter for measuring current up to 30 amperes is illustrated in

* This chapter is intended to deal with only such measuring instruments as are used in connection with ignition systems, and only to an extent sufficient to give a general idea of their nature and use. It is not thought desirable to go into details of measuring instruments in a work of this nature.

Fig. 42. The indicating needle (pointer, hand) which indicates the amount of current flowing through the ammeter is pivoted at the center of the instrument and shown pointing to zero of the graduated scale. When current is flowing through the instrument, the needle is deflected and points to the reading that

FIG. 43.

Stationary Ammeter. Weston Electrical Instrument Company, Newark, New Jersey.

corresponds to the number of amperes of current flowing. One of the terminals is the projection at the bottom of the case, and the other is at the free end of the attached wire.

When testing a primary battery, one terminal of the ammeter is electrically connected to one terminal of the battery, and the

other terminal of the ammeter is electrically connected to the other terminal of the battery. Current from the battery then flows through the ammeter. (The ammeter should not be used in this manner for testing a storage battery, unless the instrument is especially designed for such use, and current should not be allowed to flow longer than necessary to obtain a reading — not longer than two or three seconds.)

To measure the current flowing through any circuit, the ammeter must be interposed in the circuit (cut into the circuit) so that all of the current of the circuit will flow through the ammeter. Thus, the ammeter may be cut into a circuit that has a wire held by a binding screw, by disconnecting the wire from the binding screw and connecting one terminal of the ammeter to the binding screw, then connecting the other terminal of the ammeter to the disconnected end of the wire.

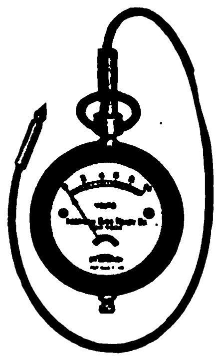


FIG. 44.
Portable Voltmeter for Measuring Electric Pressure. Small Pocket Form.

Fig. 43 is a high-grade ammeter intended to be used in a fixed position, as on a switchboard. Its range of current is from zero to 50 amperes. Similar instruments are made with ranges respectively up to 1, 5, 10, 15, 25, and 75 amperes.

48. Voltmeters. — Fig. 44 is a small portable voltmeter reading up to 10 volts. It resembles, in general appearance, the small ammeter just described. One terminal is at the bottom of the case, and the other at the free end of the attached wire.

For measuring voltage, the terminals of the voltmeter are electrically connected to the two points between which the pressure is to be measured, one terminal of the voltmeter to each point. It is immaterial whether the circuit is otherwise open or closed between the points of connection, so far as the action of the voltmeter is concerned. Thus, the voltage of a battery can be measured by connecting the terminals of the voltmeter to the terminals of the battery, either while the battery

has no other connection to it (on open circuit), or while the battery is connected in circuit and delivering current for its regular service. The reading of the voltmeter will not generally be the same under the two conditions, but this is because the difference of pressure between the battery terminals is not the same while it is delivering current as when it is on open circuit.

The amount of current that flows through the voltmeter while measuring pressure is so small as to have no appreciable effect on the action of the battery or the circuit to which the voltmeter is connected.

49. Volt-ammeters. — It is quite usual to combine a voltmeter and an ammeter in one instrument, called a volt-ammeter. In some of these only one indicating needle (hand, pointer) is used, and the reading scale has two graduations, one for amperes and the other for volts. Such an instrument cannot be used for measuring both current and pressure at the same instant. Other volt-ammeters are made up of two complete instruments, a voltmeter and an ammeter, and can be used for measuring both current and pressure at the same time.

Fig. 45 is a small portable volt-ammeter of the type having only one indicating needle. The reading scale is graduated to 10 volts and 30 amperes. The instrument has three terminals. The one at the top is for both volts and amperes. The left-hand one at the bottom is for volts, and the other for amperes. For measuring purposes, the top terminal and the left-hand one at the bottom are connected respective to the points between which the pressure is to be measured. For measuring current, the connections are made to the top terminal and the right-hand lower terminal.

A comparatively small volt-ammeter for use in connection with storage batteries (see Fig. 102) is shown in Fig. 46. Only one indicator needle is used. The needle is shown in its zero position, which is not at the end of the graduated scale. The lower scale is for amperes, and is graduated in both directions from its zero. When the instrument is used as an ammeter, the needle is deflected either to the right or the left, according to the direction in which the current is flowing through the

instrument. To obtain a voltage reading, the push-button *V* below the scale is pressed in and held while taking the reading.

Fig. 45.
Volt-ammeter for Measuring Both Pressure and Current. Small Pocket Form.

Fig. 46.
Stationary Volt-ammeter Which Indicates the Direction of Current Flow. Apple Electric Company, Dayton, Ohio.

The voltage scale is graduated in only one direction from zero.
In Fig. 47 two complete instruments, a voltmeter and an

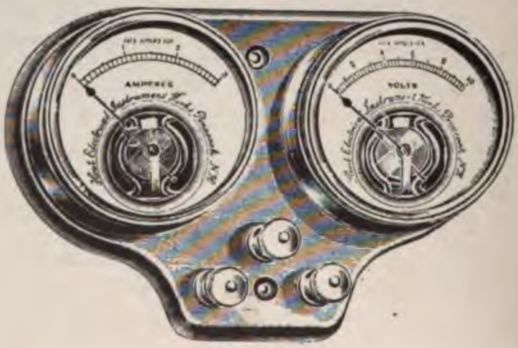


Fig. 47.
Ammeter and Voltmeter Mounted Together Permanently.

ammeter, are mounted on the same base. They can both be used at the same time, and used continuously. The instrument

is so constructed that it can be used on vehicles. The upper (middle) terminal is connected to both instruments. The right-hand terminal is for the voltmeter only, and the left-hand terminal is for the ammeter only.

50. "Dead-beat" Indicating Needle. — Unless some means is provided for quickly bringing to rest the indicating needle of a voltmeter or an ammeter, the needle will continue vibrating for a considerable time after the current is first sent through the instrument. When the instrument is moved, as on a vehicle or in one's hand, the needle may never come to rest. This vibration of the needle makes it impossible to take an accurate reading.

The better class of instruments are constructed so that the needle comes to rest quickly and stands almost without vibration even when the entire instrument is subjected to a reasonable amount of motion, yet is sensitive in its movement to indicate variation in the current or pressure. Such an indicating needle is said to be "dead-beat." This dead-beat effect is generally obtained by constructing the instrument so that the movement of the needle and its attached parts set up foucault currents that in turn resist the movement of the parts to which the needle is attached. This damping action is of much the same nature in its effect as that which can be obtained in a stationary instrument by attaching a vane, or wing, to the spindle on which the needle is mounted, and submerging the vane in a liquid.

CHAPTER VI.

ELECTROMAGNETS.

51. Plain Bar Electromagnet. — If an insulated wire is wrapped around a bar of iron or steel as shown in Fig. 48, and a direct current of electricity sent through the wire, the bar will become a magnet and remain so as long as the electricity continues flowing. When the current stops, the bar will lose nearly

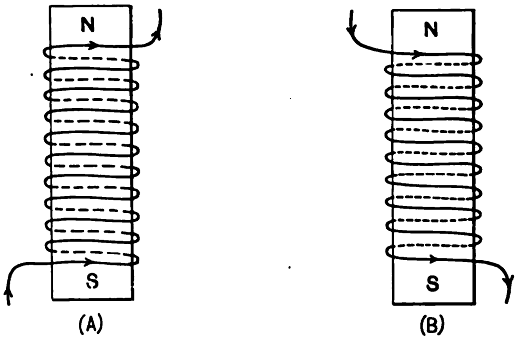


Fig. 48.
Electromagnets of Straight Bar Type.

all of its magnetism if it is of commercially pure soft iron or steel. A small amount of magnetism will remain. This is called residual magnetism. If the bar is hardened, or tempered like a sewing needle, knitting needle, or a file for working steel, it will retain a considerable amount of magnetism and be, for a while at least, a permanent magnet. If of the quality and condition of steel used for permanent magnets, it will remain a permanent magnet after the current stops and the bar is removed from the coil.

If the current flows in the direction indicated by the arrowheads on the wire, then the upper, or top, end of the bar will be

a north pole, and the lower end, or bottom, of the bar a south pole. This applies to both (*A*) and (*B*) in the figure. If the current is made to flow in the opposite direction from that indicated, then the lower end of the bar will be a north pole, and upper end a south pole. The magnetic flux *in the bar* is from the south pole to the north pole.

If the bar is held before the dial of a clock with one end pointing toward the dial, and current is flowing through the wire in the direction of rotation of the hands of the clock, then the lines of magnetic force will flow through the bar toward the clock. The north pole will be next to the clock.

Another method of determining which is the north pole is as follows: If the bar is vertical and the current in the portion of the coil between the observer and the bar flows east while the observer is looking north, then the north pole is at the top. If the bar is horizontal at the level of the observer's eyes, and the current in the portion of the wire between the observer and the bar flows downward, then the north pole is at the right-hand end.

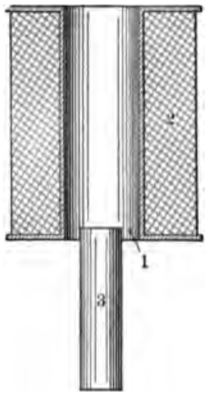


FIG. 49.
Electromagnet with Plunger Core.

52. Plunger-core Electromagnet. — Fig. 49 shows a non-magnetic spool 1 with a coil 2 of insulated wire wound around it. It may be assumed that the coil is supported in a vertical position. An iron or steel bar 3 is shown with its upper end projecting a slight distance into the opening through the spool. It may also be assumed that no current is passing through the coil, and that the bar is resting on some support, such as a table.

If an electric current, sufficiently large, is passed through the coil, the core will be drawn up into the spool and will remain suspended there as long as the current continues flowing through the coil. The bar will remain in the central part of the spool opening without touching any part. Its middle will be somewhat below the middle of the coil, on account of the weight of the bar.

As soon as the current is stopped the bar will fall. The current must be direct (not alternating).

As indicating the force with which the bar is drawn upward, it can be shot up completely through and above the spool if the current is stopped while the bar is still moving rapidly upward just after the circuit has been closed.

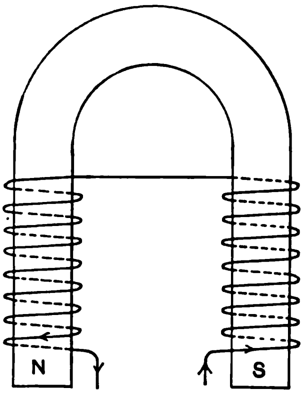


Fig. 50.
U-shaped Electromagnet.

53. U-shaped Electromagnet. — Fig. 50 shows an electromagnet shaped like the letter U in an inverted position. When a direct current flows through the winding as indicated by the arrowheads, the poles are *N* and *S*, according to the marking on the bar in the figure. If the current flows in the opposite direction, the polarity of the poles is changed.

It can be seen that, when looking at the ends of the bar, the

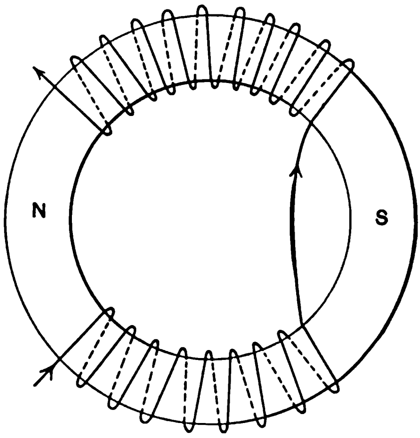


Fig. 51.
Ring Electromagnet with Consequent Poles.

current flows clockwise around the south-pole leg of the bar, and counter-clockwise around the north-pole leg of the bar. The

winding is as if the whole coil had been wound on a straight bar, and the bar then bent to the U-form.

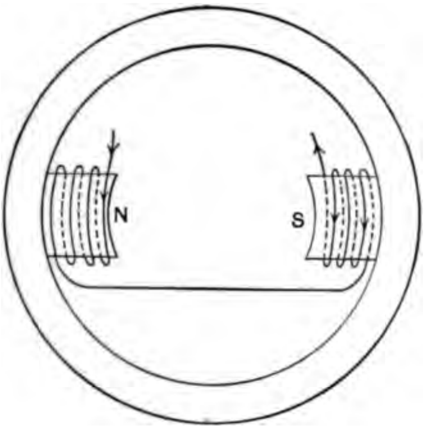


FIG. 52.
Ring Electromagnet with Two Projecting Poles.

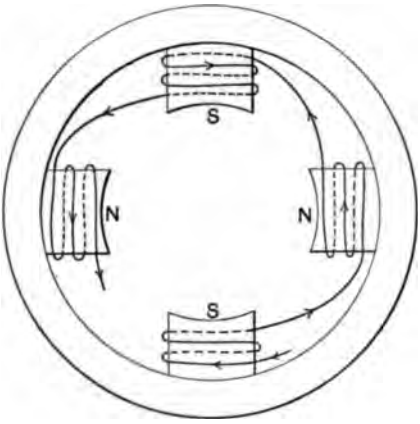


FIG. 53.
Four-pole Ring-shaped Electromagnet.

By attaching suitably formed pole-pieces to the ends of the bent bar, it can be used for furnishing the magnetic field of an electric generator.

54. **Ring-shaped Electromagnet with Consequent Poles.** — A plain ring of iron or steel can be magnetized electrically so as to make a north pole and south pole as indicated in Fig. 51. The manner of winding the coil and the direction of current are indicated in the figure. Poles located in this manner are called *consequent poles.*

By attaching suitable pole-pieces to the ring, one at *N* and another at *S*, it can be used for the field-magnet of an electric generator.

55. **A bipolar ring-shaped electromagnet with winding on** pole-pieces is shown in Fig. 52. The pole-pieces may be either an integral part of the ring, or separate parts attached to the ring by bolts or other suitable fastenings.

56. **A four-pole ring-shaped electromagnet** is shown in Fig. 53. A magnetizing coil is wound on each pole-piece. The direction of the current through each coil is indicated by the arrowheads.

CHAPTER VII.

DIRECT-CURRENT GENERATORS WITH ELECTROMAGNETS.

57. **General.** — Electromagnets can be used in conjunction with either an armature that delivers an alternating current, one that delivers a direct current, or one that delivers both direct and alternating current. When the armature delivers only alternating current, some auxiliary source of direct current must be provided for supplying electricity to magnetize the field-magnets; in other words, for exciting the field. But when the armature delivers direct current, all or part of the current can be used to excite the field-magnets, thus eliminating the necessity of the auxiliary source of current supply.

It is believed that the only type of electromagnetic generators that are used for ignition purposes is that in which the armature delivers direct current, therefore only this type will be described.

Shunt-wound Direct-current Generators.

58. **A bipolar direct-current generator with U-shaped shunt-wound electromagnets** is shown in elementary form in Fig. 54. Two circuits are connected to the brushes, one through the external circuit 1, and the other through the field-coils 2 and 3. The latter is called a **shunt circuit,** or simply a **shunt.** The shunt is a comparatively small wire of considerable length and a great number of turns around the magnet core, so that only a small proportion of the current that the armature is able to deliver passes through the field-coils.*

* The amount of direct continuous current that flows steadily through a wire is inversely proportional to the length, and directly proportional to the sectional area of the wire. A thin wire offers more resistance to the flow of current through it than a thick wire of the same material. This is analogous to the greater resistance offered to the flow of a liquid through a small pipe than through a large one. The resistance offered to flow in both the wire and the pipe is proportional to the length of the wire and the pipe.

A generator of this nature must first have its field-magnets magnetized by current from an exterior source, or by another magnet. After being once magnetized, the field-magnets retain enough residual magnetism to start the generation of a current in the armature when it is rotated, unless the magnets are subjected to some unusual demagnetizing influence.

When the armature is started to rotate, the slight electromotive force generated by the residual magnetism in the field-

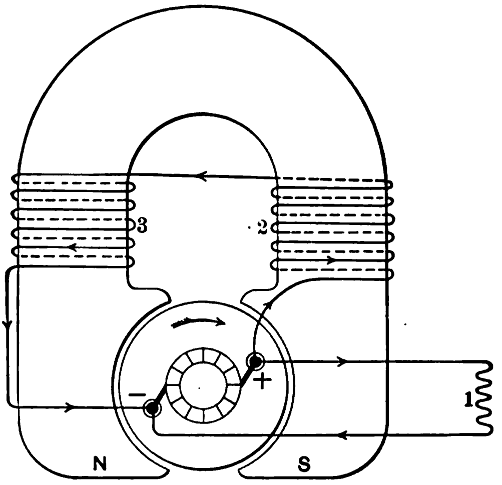


FIG. 54.

Bipolar Direct-current Electric Generator with Shunt-wound U-shaped Electromagnets.

magnets sends a correspondingly small current through the field-coils. This current strengthens the magnets, which in turn induce a greater electromotive force in the armature, and more current flows through the field-coils. By this progressive action, the generator " picks up " or " builds up " its magnetism until a condition is reached where the increase of magnetism becomes slow in relation to the increase of current in the field-coils, and a constant electromotive force is then maintained as long as the external circuit remains the same.

An increase of current through the external circuit, such as may be caused by removing a piece of apparatus from it, still leaving the circuit closed, causes a reduction of voltage at the brushes of the generator.

The generator is usually so constructed for ignition purposes that the variation of pressure at the brushes is not excessive for variations of current within the range through which the machine is designed to operate. A method of preventing this

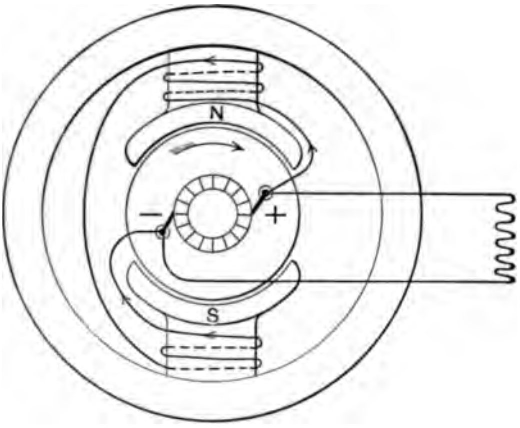


FIG. 55.

Shunt-wound Direct-current Electric Generator with Ring-shaped Bipolar Field-magnets.

drop of pressure at the brushes, by using a " compound winding " on the magnets, is given later.

59. **A bipolar direct-current generator with ring-shaped shunt-wound electromagnets** is shown conventionally in Fig. 55. The principle of operation is the same as for the generator shown in the preceding figure. It may be noted, however, that the brushes do not stand in the same position relative to the pole-pieces as they do in the former figure. In Fig. 54 the position of the brushes relative to the pole-pieces corresponds to that in Fig. 37. In order to obtain the relative positions shown in Fig. 55, the commutator in Fig. 37 may be twisted around a quarter-turn counter-clockwise relative to the armature core

without changing the connections of the wires to the commutator. In any case, the brushes can be made to stand in any position relative to the pole-pieces, by making the connections to the commutator segments accordingly.

A complete commercial machine of the type shown conventionally in Fig. 55 is illustrated in Fig. 56. The protective cap

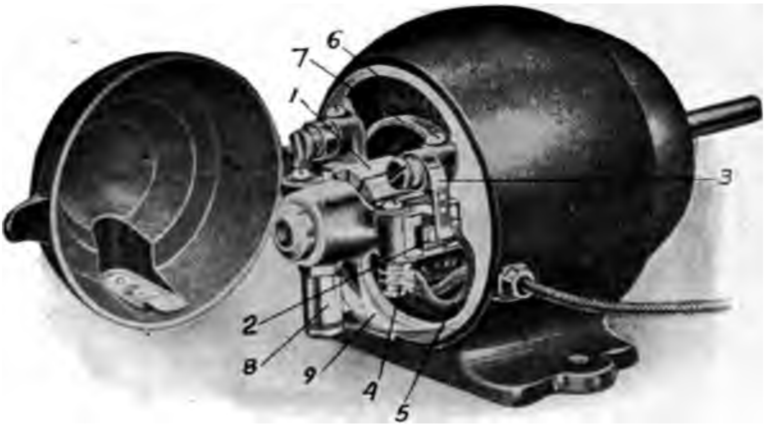


FIG. 56.

(*See also* Figs. 57, 58, 59, and 60.)

Bipolar Direct-current Electromagnetic Generator. The Dayton Electric Manufacturing Co. Dimensions in inches: 10⅞ long; 5⅝ wide; 5⅞ high.

Capacity: 3 amperes continuously. 8 volts at 1000 r.p.m. 10 volts at 1200 r.p.m.

1. Commutator.
2. Brush, insulated.
3. Brush spring, insulated at end that presses against brush.
4. Terminal.
5. Connection between brush and terminal 4.
6. Field Coil.
7. Steel tube around armature. (Discarded in later designs.)
8. Oiler with felt wick.
9. Spider with bearing for armature spindle and with brush-holders.

is opened out on a hinge at the commutator end to show the working parts. The pole-pieces are above and below the armature. The brushes are perpendicular to the commutator, so the armature can rotate in either direction. Each brush has a short ribbon spring, somewhat like a short clock-spring, for

pressing it against the commutator. The magnetizing coil 6 of the top pole-piece is partly visible. At 7 is a steel tube which fits against the pole-pieces, and inside of which the armature runs without touching it. The use of this tube has been discontinued in later designs.

FIG. 57.
Oiling Device with Felt Wick, for Fig. 56.

The armature for this machine is shown separately in Fig. 35. The oiling device is shown in Fig. 57. It consists of an oil reservoir into the top of which is fitted a round felt wick that is pressed up against the journal of the armature shaft by a coiled compression spring. The capillary action of the wick carries the oil up to the bearing gradually. The field-coils are shown in Fig. 58. Each coil is made up of insulated wire which, after being wound to form, has air and moisture removed by placing it in a vacuum, and is then insulated by impregnating it with

FIG. 58.
Field-Coils, for Fig. 56.

liquid insulating compound that hardens like varnish upon drying. The coil is then wound with insulating tape. The brushes, Fig. 59, are of graphite with a bronze-gauze core. The terminal wires are soldered to the gauze core.

Fig. 60 shows the spider 10 which supports the brushes and the commutator end of the armature spindle.

The capacity of a machine like that in Fig. 56, having the dimensions: $10\frac{7}{8}$ inches long, $5\frac{5}{8}$ inches wide, and $5\frac{7}{8}$ inches high,

FIG. 59.
Commutator Brushes, for Fig. 56.

as rated by the makers, is 3 amperes of steady current at a pressure of 8 volts when running at 1000 r.p.m., or a little more than 12 volts at 1200 r.p.m.

FIG. 60.
Bearing, Brushes, Oiler, etc., for Fig. 56.

The only means of regulating the pressure is by variation of the speed. The current is also varied in practically the same proportion as the pressure when the circuit remains unchanged. A friction pulley or a belt pulley combined with a speed governor is provided with the machine.

60. A four-pole direct-current generator with shunt-wound electromagnets is shown diagrammatically in Fig. 61. Only two brushes are used. They are placed at an angle of 90 degrees with each other of necessity. The path and direction of magnetic flux is indicated by the broken lines with double arrowheads on them.

The connections for an armature of a four-pole machine with two brushes are shown in Fig. 62. This armature has twenty-

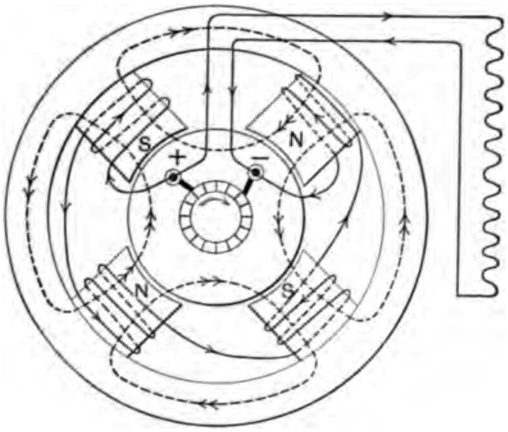


FIG. 61.
Elementary Four-pole Direct-current Electric Generator with Shunt-wound Magnets.

one coils and the same number of commutator segments, or strips. The broken lines indicate the part of the winding that is in the rear of the armature core. The core is not shown, since it would detract from the clearness of the diagram. When the direction of rotation is clockwise, as indicated by the feathered arrow, the flow of current is as indicated by the arrowheads on the lines.

Figs. 63 and 64 show a direct-current shunt-wound four-pole generator with two brushes. The former figure is partly in section. A governor spring bears against the commutator end of the armature shaft and presses the friction pulley against the flywheel that drives it. A speed governor is located on the

shaft between the friction pulley and the armature. This governor moves the entire armature and the friction pulley endwise as the speed increases, so as to reduce the pressure of the friction pulley against the flywheel, thus allowing the friction pulley

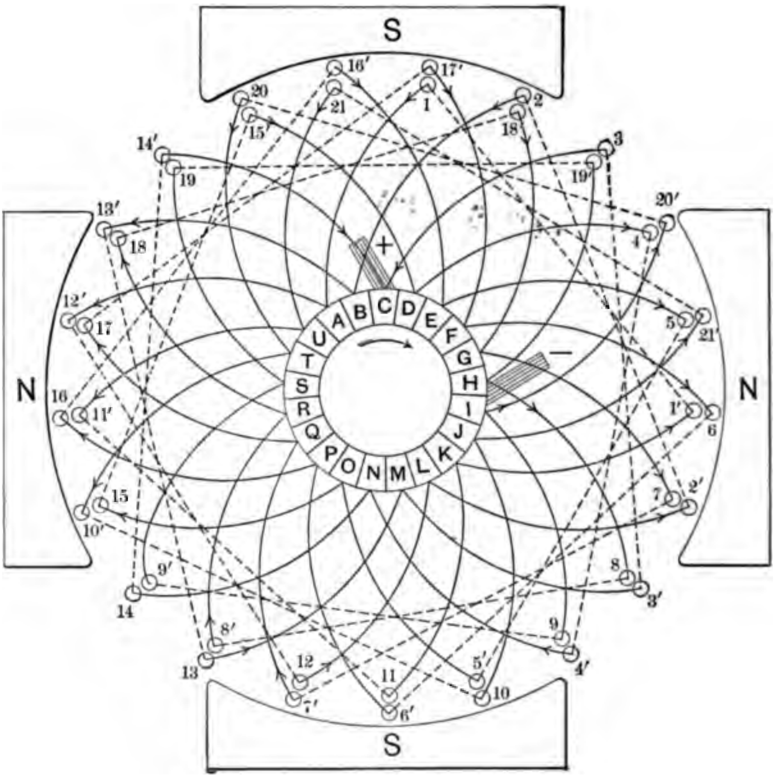


FIG. 62.
Armature Connections for Drum Armature with Twenty-one Coils and the Same Number of Commutator Segments. For Four-pole Field-Magnets.

to slip on the flywheel and limiting the speed to the desired rate. An adjusting screw is provided for varying the pressure of the governor spring against the end of the shaft so as to obtain the desired speed limit.

There are two brushes set at 90 degrees with each other. They are a combination of wire gauze and graphite. The armature

has twenty-one coils and the same number of segments in the commutator. The frame of the generator, which is also the

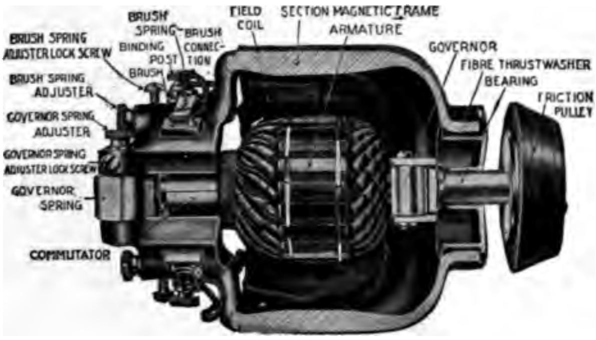


FIG. 63. (*See also* Fig. 64.)
Four-pole Direct-current Electric Generator. Sectional View. Apple Electric Company, Dayton, Ohio.

magnet ring, is cast from semi-steel. This is a material between soft steel and cast-iron in its physical and magnetic properties.

The generator is provided with an automatic cut-out for opening and closing the circuit when used in connection with storage

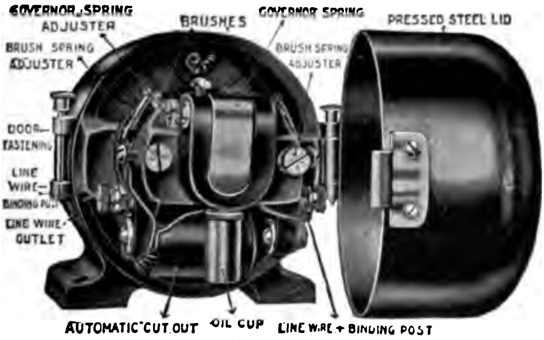


FIG. 64. (*See also* Fig. 63.)
Commutator End of Four-pole Direct-current Electric Generator.

batteries. This method of using is described later in connection with a complete ignition system (see Fig. 95 and several following figures). The machine is also equipped with a device for keeping the current nearly constant when the speed of the

armature is variable. This device automatically changes the amount of resistance in the field circuit.

Compound-wound Direct-current Generators.

61. Series-and-shunt Field Winding. — It is often desirable to have a generator that will keep the voltage at the brushes practically constant when the rotative speed of the generator is constant, so that the pressure will be practically constant whether

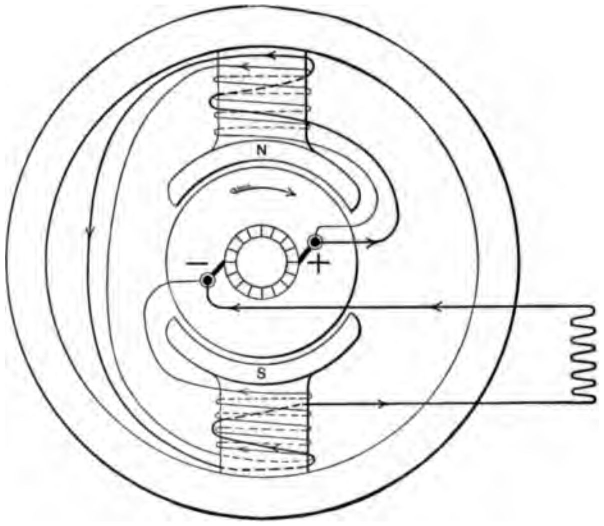


FIG. 65.
Compound-wound Direct-current Electric Generator.

the amount of current delivered is variable or constant. This is accomplished by means of a double winding on the field-magnets. One of the windings is the regular shunt winding, and the other winding carries the current that flows through the external circuit. The latter is called the series winding. Fig. 65 shows diagrammatically a generator with compound field winding of this nature.

The currents in both windings flow in the same direction around the magnet cores. It has been explained that the voltage at the brushes drops as the external current increases when only

a shunt winding is used. This tendency is counteracted by the magnetizing effect of the current which flows through the series coil. The magnetizing effect of the series coil increases as the current through the series coil and external circuit increases. By giving the series coil a suitable number of turns around the magnet core, the voltage at the brushes can be kept almost constant in a properly designed machine. By giving the series

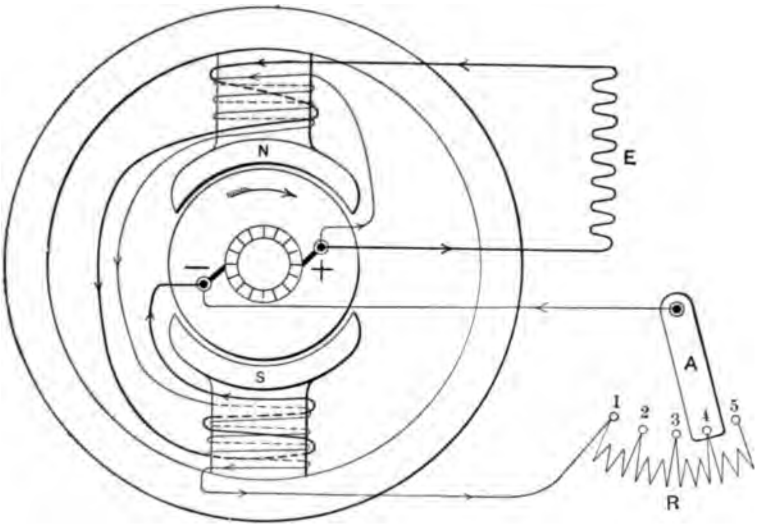


FIG. 66.
Rheostat in Shunt-coil Circuit of Electric Generator.

coil more than this number of turns, the voltage can be made to rise as the current in the external circuit increases. This over-compounding is often desirable.

The voltage of a compound-wound machine such as shown in Fig. 65 is approximately proportional to the speed of the armature, within the range of speed at which the machine is designed to operate.

62. Field Rheostat for Regulating Voltage. — When the rotative speed of the armature of an electromagnetic generator is constant, the voltage at the brushes can be regulated by varying

the electrical resistance of the shunt-coil circuit. The usual means of doing this is a rheostat.

Fig. 66 shows a compound-wound generator with an elementary form of rheostat in the shunt circuit. The principal parts of the rheostat are shown at *A* and *R*. *R* is a series of coils of wire. The ends of the wire are connected to metal contact-points 1, 2, 3, 4, and 5. These points are arranged in an arc of a circle. A switch-arm *A* is pivoted at the center of the arc and is of such a form that it can be moved into contact with any of the contact-points just enumerated. This rheostat is interposed in the shunt circuit by cutting the shunt wire at any convenient point and connecting the wire-ends thus obtained to the rheostat as shown. One end is connected to the contact-point 1, and the other end to the pivot of the arm *A*.

When the rheostat arm *A* is set in contact with point 4 as shown, the shunt current must pass through the rheostat coils that lie between 1 and 4, and the resistance of these coils is added to that of the field-coils. The current that flows through the field-coils is therefore less than would flow if the rheostat were not in the circuit, and the voltage at the brushes is in consequence less than it would be without the rheostat. By moving the arm into contact with either 3, 2, or 1, the voltage can be increased; or by moving it to 5, the voltage can be decreased.

The swinging end of the contact arm *A* is wide enough to touch two of the contact-points at the same time when moving from one to another. This is necessary in order to prevent breaking the circuit while varying the resistance in the circuit.

The rheostat is generally a separate piece of apparatus. The resistance wire used in it is ordinarily of a material that has high electric resistance compared with that of copper.

A rheostat can be used in the field circuit of a plain shunt-wound machine as well as in one that is compound-wound.

Reversing the Rotation of the Armature.

63. Most of the generators for ignition usage have the brushes perpendicular to the commutator so that the armature can be rotated in either direction without injury.

The field-coil connections to the brushes must be interchanged when the direction of rotation of the armature is to be reversed. If the armature is run in the new direction without making this change of connections, it will not pick up its magnetism and generate a current. This is because the different direction of rotation changes the polarity of the brushes, so that the one formerly positive becomes negative, and the former negative one becomes positive. The current which is generated by the residual magnetism therefore flows through the field-coils in the direction to demagnetize them instead of strengthen their magnetism. The result is that no appreciable pressure is generated, and of course no appreciable current can be obtained without corresponding pressure.

CHAPTER VIII.

PRIMARY BATTERIES.

Carbon-zinc Battery.

64. When an electric battery is subject to considerable motion, as in automobiles, railway motor cars, and motor boats, a "dry battery" is almost exclusively used if ignition current is supplied by a primary battery. The dry primary battery is also much used for ignition in stationary motors.

Only one of almost innumerable types of dry batteries, as distinguished by the substances used in them, is used to a noticeable extent. In this commonly used battery the substances which designate it are carbon, zinc, and sal ammoniac (also called ammonium chloride, NH_4Cl). Other substances are used in connection with these and are essential to its operation for supplying current for motor ignition. In order to make clear the nature of this battery cell and its operation, the elementary form using only carbon, zinc, and sal ammoniac will be first described.

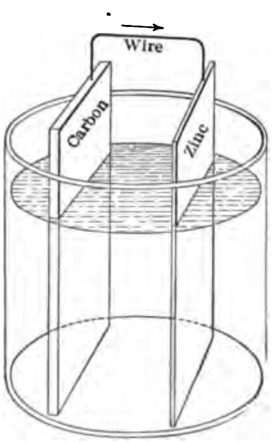


Fig. 67.
Elementary Wet Electric Battery Cell.

65. Elementary Leclanché Carbon-zinc Wet Cell. — A bar of zinc and a slab of carbon immersed in a solution of sal ammoniac in a glass vessel are shown in Fig. 67. The solution is made by dissolving sal ammoniac (a white salt) in water.* The carbon and zinc are connected together by a wire.

* One-quarter pound of sal ammoniac to a quart of water is the proportion generally used in a cell.

A current of electricity begins to flow from the carbon to the zinc through the wire as soon as the carbon and zinc are immersed in the solution. The current also flows through the solution from the zinc to the carbon *inside of the cell.* The amount of current decreases very rapidly immediately, and then continues to decrease at a slower rate till, after considerable time, there is scarcely a perceptible flow. The cause of the decrease of current is called polarization, and is described below.

Decrease of current on account of polarization also occurs in this elementary form of cell when it is used in the manner required for motor ignition. This action makes it unsuitable for motor ignition purposes.

The electric current through the wire is generated by chemical action between the zinc and the solution. The solution attacks the zinc and combines with it. This action dissolves, corrodes, or eats away the zinc.

The above combination is called a primary electric cell. In earlier days it was commonly called a galvanic cell or a voltaic cell. Two or more such cells properly connected together form a battery of cells, called an electric battery. In commercial usage a single cell is generally also called a battery.

The carbon and zinc are called the electrodes, and the solution is called the electrolyte. All three together are called the active elements of the cell.

The point at which the wire is attached to the carbon is the positive (+) terminal of the cell; and the point of attachment of the wire to the zinc is the negative (−) terminal of the cell.*

In commercial forms of cells, binding screws and nuts, or other suitable fastenings, are usually provided for attaching wires at the terminals.

If the wire is cut in two and the ends separated, the flow of current through it is stopped. The chemical action in the cell

* On account of the confusion which arises when one of the elements of the cell is referred to as the positive electrode, and the other as the negative electrode, the terms positive electrode and negative electrode are not used herein in connection with electric cells and batteries. The terms anode and cathode are omitted in connection with batteries for the same reason.

also stops with the stoppage of current through the wire, except that there is generally some slight amount of local action on the zinc. Impurities in the zinc, such as iron and copper, increase this local action. But even if the zinc is very pure, local action will still occur on account of a difference in the strength, or quality, of the portion of the solution at the top and that at the bottom. The local action due to this latter cause eats away the zinc at and near the surface of the solution. Local currents through the zinc are caused by this action.

The electromotive force of a primary cell with carbon and zinc electrodes in sal-ammoniac solution is slightly less than 1.5 volts between the terminals after the cell has not been delivering current for some time. The voltage drops as soon as the circuit is closed and current begins to flow. It slowly rises again to its full value after the current is stopped by opening the circuit.

66. Polarization of Primary Electric Cell. — The decrease of current that occurs while the circuit of a cell is kept closed, in the case of a cell having only the elements carbon, zinc, and sal ammoniac, is due to the formation of hydrogen gas by the chemical action. The gas collects on the carbon and retards chemical action. This retardation is apparently chiefly due to a counter-electromotive force which the hydrogen sets up, and also partly due, but to a less extent, to the formation of bubbles on the carbon so as to prevent the electrolyte from having as good contact with the carbon as it has before any bubbles are formed. If the carbon is molded very dense and has a very smooth surface, polarization can be at least largely prevented by constantly brushing off the bubbles of hydrogen. This is not practicable, however. The usual method is to prevent polarization by chemical means. This is ordinarily called depolarization. It is successfully applied to both wet cells and dry cells.

67. A dry cell with carbon and zinc electrodes and chemical depolarizer is shown sectionally in Fig. 68. This is the type of dry cell that is almost universally used for ignition where the battery is subjected to much motion.

The containing vessel, cup, or can 1 is made of sheet zinc and

is one of the electrodes. The can is lined with absorbent paper 2 (blotting paper) that is saturated with water in which sal ammoniac and zinc chloride have been dissolved. In the center is a molded bar of carbon 3 around which is packed a mixture 4 of manganese dioxide (MnO_2) and carbon dust. The manganese dioxide is in granular form (powder). The paper is turned in over the top of the mixture so as to cover it nearly or completely. On top of the paper is a little sawdust or sand, and above this a sealing compound 5, composed chiefly of pitch, to make the cell water-tight. The absorbent paper and the mixture around the bar are saturated with the electrolyte before the cell is sealed. The carbon in the mixture is generally coke-dust, and the carbon bar is made of coke-dust mixed with a binder such as pitch. The plastic mixture for the bar is molded to form and then baked to give it strength and at the same time convert the binder into carbon. Carbon is a better conductor of electricity than manganese dioxide, hence mixing it with the manganese dioxide gives the cell less resistance to the flow of electricity than if manganese dioxide alone were used around the bar. A low resistance is desirable in a dry cell, especially one that is to be used for gas-engine ignition.

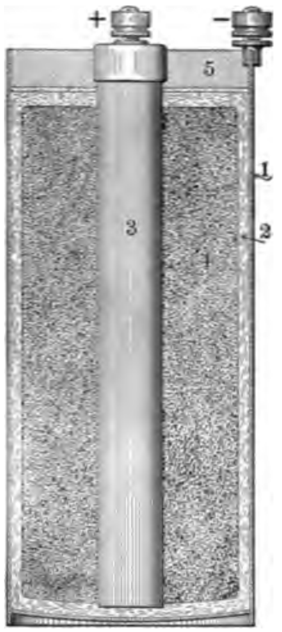


FIG. 68.
Dry Cell of an Electric Battery.

The carbon bar is capped with a tight-fitting brass piece which has a binding screw and nut. Another binding screw is soldered to the top of the zinc can. The cap on the carbon bar at the center of the cell is the positive (+) terminal, and the binding screw fastened to the zinc can is the negative (−) terminal.

The manganese dioxide is a depolarizer. It gives up oxygen,

which combines with the hydrogen gas that is liberated by the action described in connection with the elementary carbon-zinc cell. The hydrogen and oxygen combine in the proportion to form water, which is a liquid and remains in the cell.

The electromotive force of a dry cell of the kind just described is about 1.5 volts on open circuit when new and in good condition, irrespective of the size of the cell. A large cell will give more current than a small one.

The size of dry cell which has become standard is 2½ by 6 inches long. It is cylindrical in form. The cell is usually covered with some insulating material, such as paper or straw-board, except the terminals. This insulating covering prevents the metal of one cell from coming into contact with that of another when the cells are grouped together to form a battery. A cell of this size will give from 15 to 20 amperes of current through a low-resistance ammeter when the circuit is first closed. The cell is practically short-circuited when its terminals are connected through a low-resistance ammeter, the resistance of the latter being about the same as that of a short, heavy copper wire. The cell will deliver this maximum amount of current during only a few seconds. The current rapidly decreases when the cell is short-circuited, but continues with constantly decreasing value till the battery is exhausted.

The exhaustion of a dry cell of the usual construction is due to weakening of the liquid electrolyte with which the absorbent paper in the cell is saturated. This weakening is on account of the chemical action necessary to produce electric current.

68. Deterioration of new permanently sealed dry batteries often occurs to a marked extent before they are put into use. They sometimes deteriorate in a few months or less of storage so as to become useless. Such rapid deterioration is not apt to occur in well-made cells whose materials are suitably pure.

69. New Type of Carbon-zinc Dry Cell, not Sealed. — A type of dry cell which is actually and thoroughly dry until put into use was first exhibited at the Atlanta automobile show in the latter part of the year 1909. The cell resembles in general

appearance and construction the one shown in Fig. 68, except the carbon rod and the terminal on it.

The carbon rod of the new cell is made hollow and is provided with a wooden stopper at the open end. The terminal is fastened to one side of the top of the carbon. When the cell is manufactured it is left entirely dry, but all of the necessary chemical elements are put in it. It is chemically inactive and does not deteriorate in storage before putting into use.

To prepare the cell for use, it is only required to fill the hollow carbon rod with water, after removing the stopper, which is replaced after the water is poured in. The water dissolves the chemical elements which with the water form the electrolyte. After being thus put into operation, the cell is subject to exhaustion and deterioration the same as a permanently sealed cell of the same quality.

70. Exhaustion and Running Down of Dry Batteries in Service. — The chemical action in the cell by which electric current is generated of course consumes the active materials and produces new chemicals. The result is a dropping off of the activity of the cell and finally its exhaustion to such an extent that it becomes useless.

In a properly constructed cell, the chemical elements are so proportioned that they become exhausted at about the same time. The zinc cup is not much thicker than necessary to furnish the requisite metal for the amount of chemicals present. The fact that the zinc is sometimes eaten through before the cell is nearly exhausted is an indication of local action in the zinc, probably on account of impurities in the metal. Local action is more apt to make itself known when the battery is allowed to stand idle during a considerable portion of its life.

71. Recuperation of dry cells can generally be effected by adding sal-ammoniac solution to the inside of the cell. The solution can be added to a permanently sealed cell by making an opening through the sealing compound at the top so as to expose the blotting paper, and pouring the liquid into the opening. The sealing compound can be readily dug out with a pointed instrument. It is not necessary to replace it, since the

cell will never be of much use after becoming exhausted the first time. This expedient of recuperation is hardly worth while except in case of emergency.

It is probable that the new type of unsealed cell described above can be recuperated by pouring in a solution of sal ammoniac after the cell has been run down in service.

The addition of water alone will sometimes recuperate a cell slightly.

Copper Oxide and Zinc Wet Cell.

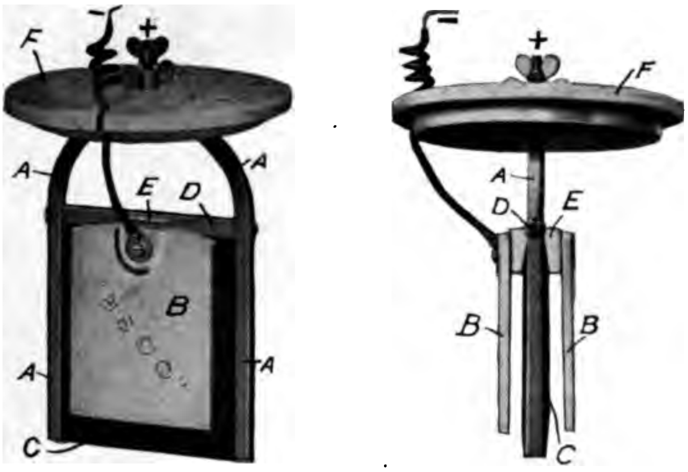
72. The Lalande and Chaperon wet cell, as brought out in 1881, has zinc amalgamated with mercury for one electrode, and either iron or copper for the other. The electrolyte is a solution of either caustic soda (concentrated lye, sodium hydrate, NaOH) or caustic potash (potassium hydrate, KOH). A depolarizer of copper oxide (cupric oxide, CuO) is used. Modified forms of this cell, one known as the Edison-Lalande and more recently as the Edison primary battery, and the latest one as the BSCO battery, are used to a considerable extent for gas-engine ignition, especially for stationary engines.

FIG. 69. (*See also* Figs. 70 and 71.)
Copper Oxide and Zinc Wet Cell. Edison Manufacturing Company, Orange, New Jersey.

73. A BSCO wet cell is shown in Fig. 69. Part of the containing vessel is broken away to show the interior construction. The electrodes, depolarizer, and the cover of the cell are shown removed from the cell in Figs. 70 and 71.

The copper electrode has the form of an inverted U-shaped, grooved, or channeled, frame *A* which hangs from the cover *F* of the cell, the connection being made by a bolt which passes through the cover and has thumbscrews above it. The depolarizer slab *C* is clamped between the legs of the copper frame, which are drawn together against the beveled edges of the slab by means of a copper cross-bar, or bridge, *D*, so as to make good electric contact between the copper and the depolarizer slab.

The lower ends of the copper frame are bent in under the slab to support it. The zinc plates *B* are suspended from the crossbar by means of a steel bolt which passes through a porcelain insulator *E* and holds the zincs firmly in place. The porcelain insulates the zincs from the copper. An insulated wire is connected to the zincs, and its outer free end is the negative (−)



FIGS. 70 and 71.
Elements and Top of Fig. 69.

terminal of the cell. The bolt from which the copper frame is suspended is the positive (+) terminal.

The depolarizer slab is a mixture of copper oxide and magnesium chloride compressed to form in molds and then heated to make it a firm mass. The magnesium chloride acts only as a binder to hold the mass together.

The zinc plates are amalgamated by incorporating about two per cent of mercury with them when they are cast.

The liquid electrolyte covers the zinc plates completely to a depth of an inch or so above them. A layer of heavy mineral oil is poured on the electrolyte and floats at the top to protect the electrolyte from atmospheric action. If air is allowed to come into contact with the electrolyte, it oxidizes it and decreases the length of life of the cell.

Since the rigid parts of the cell are firmly fastened together, the cell can be used where there is motion without danger of the electrodes coming into contact with each other or with other parts so as to short-circuit the cell. It can therefore be used on vehicles if the top is sealed on, for which provision is made in one type of the cell intended for ignition use. Cells for portable use are made with enameled steel containing vessels, or jars.

The voltage of one of these cells on open circuit is slightly less than one volt. The pressure does not drop much below one volt during use until the battery is nearly exhausted.

The renewals for an exhausted battery consist of the parts suspended from the cover, which are sent out as a unit fastened together, and the electrolyte of dry caustic potash to be dissolved in water. The oil for covering the electrolyte may also be included as one of the renewal items. Renewal of the parts is made by taking out the bolt which passes through the cover, discarding the copper frame and parts attached to it, and fastening the new frame and its attached parts in place with the old cover-bolt; also discarding the exhausted electrolyte and dissolving the new in water poured into the jar.

FIG. 72.
Early form of Edison Primary Battery shown in Fig. 69.

The capacity of the portable cell intended for ignition use is 200 ampere-hours.

74. The Edison primary battery, already referred to as an earlier form of the one just described, differs from the newer form only in mechanical construction. One of these earlier cells is shown in Fig. 72, with part of the jar broken away to show the interior. The zinc plates are suspended from the porcelain cover, instead of from the copper frame, as in the later form, and the copper frame is of different form, with a bolt connecting the two sides under the depolarizer slab. The zincs are not so firmly and accurately held in place as in the later type of cell. The cell is therefore not so well adapted to portable use as the latter type.

The capacities and dimensions of some of these cells are given in the following table according to the Manufacturer's rating:

Diameter and Height over All. Complete Cell with		Capacity in Ampere-Hours.
Porcelain Jar.	Enameled Steel Jar.	
Inches.	Inches.	
$4\frac{1}{2} \times 7\frac{3}{4}$	$4\frac{1}{2} \times 6\frac{3}{4}$	100
$5\frac{3}{4} \times 8\frac{3}{4}$	$5\frac{3}{4} \times 8$	150
$7\frac{1}{4} \times 10\frac{1}{2}$	$7\frac{1}{4} \times 10$	300

CHAPTER IX.

BATTERY CONNECTIONS.

75. General. — In order to obtain suitable electromotive force and current, cells are connected together to form a battery. The best arrangement of the cell with regard to the order in which their terminals are connected together depends on the nature of the service to be performed and on the resistance of the external circuit.

In the following discussion it is assumed that all of the cells in a battery are alike. This assumption is in accordance with the best practice. Moreover, the discussion relative to different kinds and capacities of cells grouped together in a battery is more complicated than is thought should be presented in a work of this nature.

For convenience of discussion, it will be assumed that either carbon-zinc cells or copper-zinc cells are used. The carbon terminal, or the copper terminal, as the case may be, is the positive one, and the zinc terminal is the negative one.

Series-connected Batteries.

76. A series-connected battery of four cells, all alike, is shown in Fig. 73. The carbon terminal of each cell is connected to the

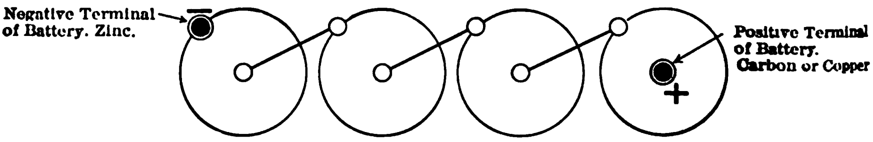


FIG. 73.
Electric Battery of Series-connected Cells.

zinc terminal of another cell, except that the carbon terminal of the right-hand cell and the zinc terminal of the left-hand cell

are left free. These two free terminals are the terminals of the battery.

The voltage of a series-connected battery, measured between its terminals, is equal to the sum of the voltages of all of the cells. In this case the battery voltage is four times that of one cell, since there are four cells, all assumed to be alike. If the electromotive force of one cell is 1.5 volts on open circuit, then the electromotive force of the battery of four cells is $4 \times 1.5 = 6$ volts. If the electromotive force of each cell drops to 1.25 volts when the battery is delivering current in regular service, then the working voltage of the battery is $4 \times 1.25 = 5$ volts.

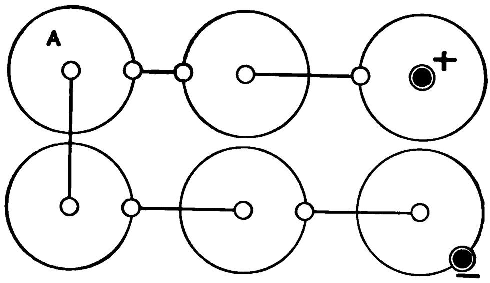


FIG. 74.
Reversed Cell in a Battery Intended to be Series-connected.

The current that the battery will give is greater than a single cell will give. The increase of current obtainable by connecting the cells together is not so great in proportion as the increase in the number of cells in the battery. With the four cells, it is not possible to get four times as much current as from one cell. The current will be very nearly four times as great with the four cells, however, if the resistance of the external circuit is very great in comparison with the internal resistance of the battery. The internal resistance of the series-connected battery is the sum of the internal resistances of all of the cells. If the external resistance is very low compared with the internal resistance of the battery, the series-connected battery will give only very little more current than one cell alone will give.

77. Reversed Cell in a Series Battery. — If one of the cells is

wrongly connected to its neighbors in a series battery, so that its carbon is connected to the carbon of one adjacent cell, and its zinc to the zinc of the other adjacent cell, the effect on the voltage of the battery is equivalent to removing two cells from the battery. It requires the electromotive force of one of the properly connected cells to counteract that of the reversed cell. The current that the battery will give is less than that of a properly connected series battery with two less cells.

Fig. 74 is a six-cell battery intended to be series-connected, but one cell *A* is reversed. The battery is therefore somewhat less effective and efficient than a properly connected four-cell series battery. While this error of making connections appears plain on paper, it is one that frequently occurs and is not so easy to notice in practice.

Multiple- or Parallel-connected Batteries.

78. A parallel-connected battery of four cells whose positive (carbon) terminals are all connected together by one wire, or other conductor, and whose negative (zinc) terminals are all connected together by another conductor, is shown in Fig. 75.

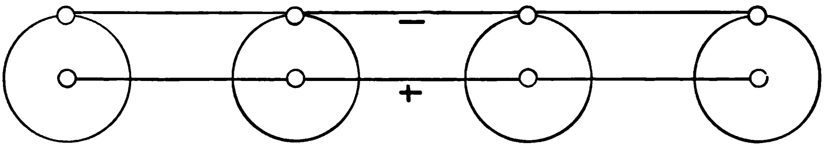


FIG. 75.
Parallel or Multiple Connection of Cells in a Battery.

Any place on the wire connected to the carbons can be taken as the positive terminal, and any place on the wire connected to the zincs as the negative terminal.

The voltage of the battery is the same as that of one cell. When connected to an external circuit of very high resistance, the battery will deliver only slightly more than the amount of current in amperes that one cell will deliver to the same circuit. But when the positive and negative wires of the parallel-connected battery are connected together by a conductor of very

low resistance, such as a thick, short copper rod, the four cells will give nearly four times as much current as one cell with its terminals similarly connected together.

In general, the current is but slightly increased by putting cells in parallel if the resistance of the external circuit is high, but if the external resistance is low compared with that of the battery the current is materially increased.

79. Reversed Cell in a Parallel-connected Battery. — In Fig. 76 three cells, 1, 2, and 3, are connected together. The zinc of cell 1 is connected to the carbons of cells 2 and 3, and the carbon of cell 1 is connected to the zincs of 2 and 3. When the cells are connected together in this manner, current flows from the carbon of cell 1 to the zincs of 2 and 3, and from the carbons of cells 2 and 3 to the zinc of 1. The resistances of the circuits are low, being only that of the connecting wires and of the cells. The internal resistance in circuit is one and one-half times that of one cell when they are connected in this manner. Unless the connecting wires are very unusually thin and long,

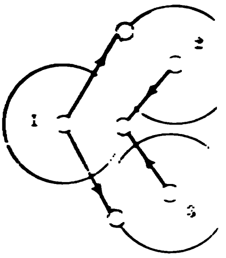


Fig. 76.
Wrong Connection of Cells in a Battery.

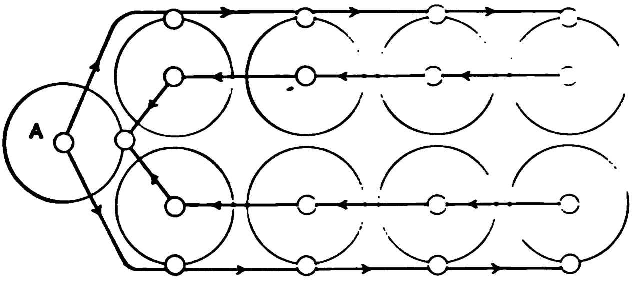


Fig. 77.
Reversed Cell in a Battery Intended to be Parallel-connected.

the total resistance of the circuit, internal plus external, is not more than that of two cells added together. The result is that a large amount of current flows and the cells become exhausted in a short time.

Fig. 77 shows nine cells, eight of which are connected in parallel, but the remaining one A is reversed from the position proper for parallel connection with the others. The result is of the same nature as that just stated for three cells. Current flows as indicated by the arrowheads on the wires. The current is not of the same amount in all parts of the wires, however. It is greater in the wires which are between the cells near A than in those between the cells more remote from A. All of the cells will be rapidly exhausted.

Parallel-series Batteries.

80. Fig. 78 shows two sets of series-connected cells with four cells in each set. One set is made up of cells 1, 2, 3, and 4; the

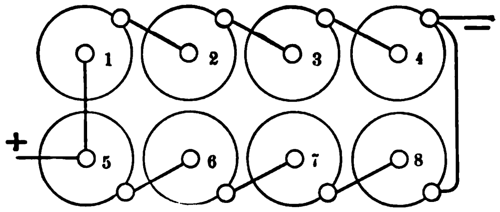


Fig. 78.
Parallel-series Battery Connection of Two Sets of Series-connected Cells.

other set is made up of cells 5, 6, 7, and 8. The two sets are connected together in multiple, or parallel. Any point on the wire connecting the two carbons can be taken as the positive (+) terminal of the battery, and any point on the wire connecting the two zincs can be taken as the negative (−) terminal.

The voltage of the parallel-series battery is the same as that of each series of cells. In this case the voltage is four times that of one cell, since there are four cells in each series.

More current will be sent through the external circuit by the two sets of series-connected cells than by one series alone. The increase of current will be greater when the external resistance is low than when it is high. It is sometimes convenient to consider each series as a unit whose terminals are those of the series.

When this is done the series can be dealt with as a single cell so far as regards its relations to other units of a similar nature.

In Fig. 79 five sets, each of four series-connected cells, are connected in parallel, or multiple, with each other. The cells

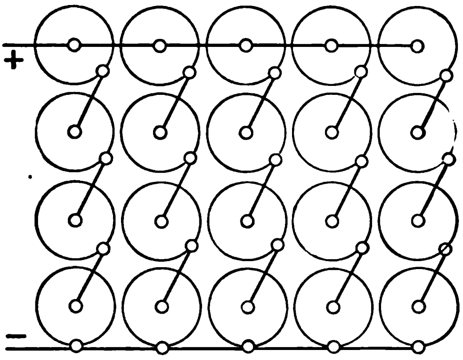


FIG. 79.
Parallel Connection of Five Sets of Series-connected Cells.

of each series are in a vertical row in the illustration. The voltage of the battery is four times that of one cell.

81. Wrong Arrangement of a Battery. — In Fig. 80 five series-connected cells are shown in the upper row, and four series-

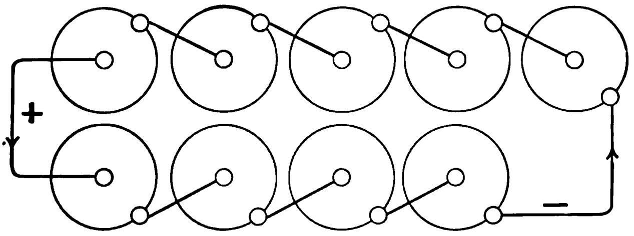


FIG. 80.
Wrong Arrangement of a Battery.

connected cells in the lower row. The two series are connected in parallel with each other. The result is that current flows through the battery while the external circuit is open, on account of the electromotive force of the upper row of five cells

being greater than that of the lower row of four cells. The direction of the current is indicated by the arrowheads on the wires. The current will continue until the electromotive force of the five cells in series drops to that of the four series-connected cells. This action means exhaustion of the five cells. A battery should not be made up in this manner.

82. Connection to External Circuit. — The method of connecting two series batteries to the same external circuit is shown in Fig. 81. The negative terminal of each series of cells is connected to one of the contact-points, or poles, of a two-point switch. The contact-points are insulated from each other and from other parts of the system. The positive terminal of each

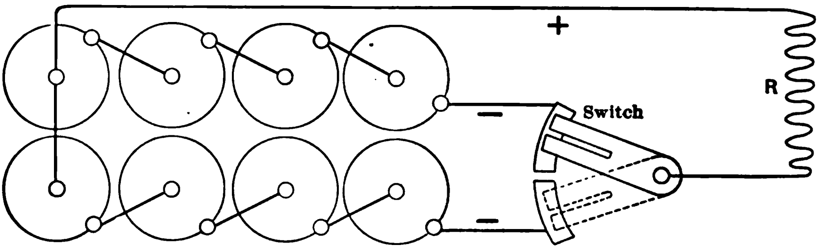


Fig. 81.
Correct Method of Connecting a Battery to the External Circuit.

set of series-connected cells is connected to the external circuit *R*, from which connection is made to the switch-blade. When the switch-blade is in the position shown, the upper row of cells is the only one that delivers current. The other row of cells is on open circuit. If the blade is moved into contact with the lower switch-point, as indicated by the dotted lines, then the lower row of cells is brought into operation alone. By placing the switch-blade in mid-position, so that it has contact with both switch-points, the complete battery is cut into circuit and it all acts to furnish current to the external circuit. By throwing the blade over so that it has no contact with either point, the current is completely cut off from the external circuit and there can be no local current in the battery of the nature of that in Fig. 80, because there is no connection between the negative

terminals when the switch-blade has no contact with either point of the switch.

It may be noted that, even when two series, both of the same number of cells, are in parallel with each other, and one series is run down or exhausted, while the other is in good condition, there will be local current in the battery of the same nature as that in Fig. 80.

83. Screw-top Battery Cells. — An exceedingly convenient way of connecting cells together in a battery is by means of a

FIG. 82.
Screw-top Cells and Battery Box. Stanley & Patterson, 23 Murray Street and 27 Warren Street, New York City.

screw top on each cell and a plate provided with suitable contact pieces and connections. Such cells and a plate are shown in Fig. 82. It is only necessary to screw the cells into the plate in order to make the proper connections. The making of wrong connections, which is not an unusual happening with the ordinary cells, each having two terminal nuts, is thus entirely eliminated. The cell is connected into the battery in a manner similar to that in which an incandescent electric lamp is connected into the circuit of the service wires. The carbon terminal of the battery cell makes contact with a spring, and the zinc shell makes contact with the threaded metallic ring into which it screws.

The spring keeps the contacts pressed together and prevents their jarring loose.

The cells are also made with combination screw-top and binding-post terminals. By means of the latter the cells can be connected together with wires when desired.

FIG. 83. (*See also* Fig. 82.) Screw-top Spark-Coil and Cells in Battery Box.

By the use of "emergency spring clips" the ordinary type of cell with two binding posts can be used in the cap or plate.

Fig. 83 shows five dry cells and a spark-coil (spark-coils are described later), each screwed into its receptacle in the top-plate of the battery box. The spark-coil occupies practically the same amount of space as one of the cells.

Battery boxes with this form of connection are also made up with two sets of cells and a switch which, when moved to its different positions, connects the two sets of cells either in parallel or in series, or connects either of the sets into the system, leaving the other idle.

The boxes are made water-tight for marine use or for any place where there is much water or moisture.

CHAPTER X.

STORAGE BATTERIES, ALSO CALLED ACCUMULATORS AND SECONDARY BATTERIES.

84. A storage battery is one that must be charged by passing an electric current from some exterior source through it in order to bring it into a condition in which it can deliver an electric current. Before charging by passing an electric current through it, the storage battery is inert and cannot deliver current. After it has been once charged and then discharged by delivering current, it can be recharged and will again furnish current till it is discharged a second time. Charging and discharging can be repeated numerous times.

The charging current while passing through the battery effects chemical changes in the elements of the battery. These chemical changes take place in both of the electrodes and in the electrolyte. During discharge the reverse chemical actions occur and bring the battery elements at least partly back to their conditions before charging.

The name " storage battery " is a misnomer, strictly speaking. Electricity is not actually stored in the battery. The charging current passes through and out of the battery, effecting chemical changes in the elements of the battery during its passage. The distinction between this action and the actual storage of electricity will appear later in connection with electric condensers.

While a great variety of storage batteries have been constructed and tried out, those in commercial use are limited almost exclusively to two kinds as classified by the materials used in them. Of these two types, the one which is used by far the more generally is known as a " lead accumulator " or " lead storage battery," on account of its electrodes being made of the metal lead and oxides of lead. The other type is known as the " Edison

storage battery." Its electrodes are composed chiefly of nickel and iron.

85. The electrodes, or plates, of a lead storage cell are usually made up of plate-shaped pieces of lead, or lead alloy, which have perforations, pockets, or other forms of receptacles filled with the electrically active material. This active material is usually put into the pockets in the form of paste during the construction of the cell. It is composed chiefly, when first put in, of an

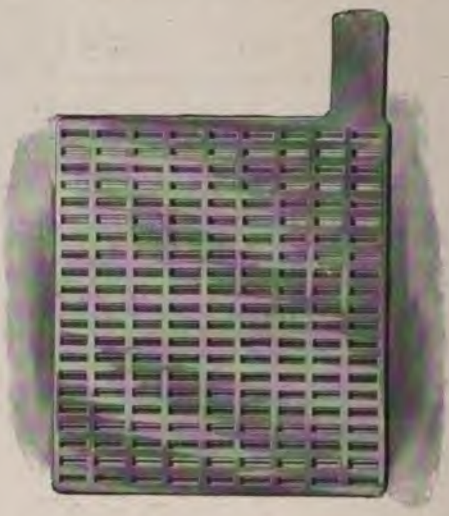


FIG. 84.
Electrode, Plate, or Grid of a Lead Storage Battery.

oxide, or oxides, of lead. The plates are then treated chemically and electrically so as to cause the paste to set firm and hard, and to change its chemical composition. The plate, or plates, to form the electrode to which the positive terminal of the cell is connected are treated so that the final condition of the paste is dioxide of lead (PbO_2), and the plate has a brown color, including the paste. The plate, or plates, to form the other electrode are treated so as to remove the oxygen from the compound and leave metallic lead in a porous, or spongy, condition with the characteristic color of metallic lead.

One form of lead grid for a storage battery is shown in Fig. 84. It has rectangular perforations for receiving and holding the paste. The lug projecting upward is for making connection to other plates or to the external circuit.

86. Complete Storage Cell. — Fig. 85 shows several complete plates grouped together to form the electrodes of one cell. Three

Fig. 85.
Group of Plates for a Lead Storage Cell.

of the plates are fastened together by a bar, or strap, which carries one of the terminals of the cell at the top. The other two plates are fastened together in a similar manner and have the other terminal of the cell at the top. The pockets of the plates, or grids, are shown filled with paste.

Separators are used between the plates to keep them from coming into contact with each other. One of the separators

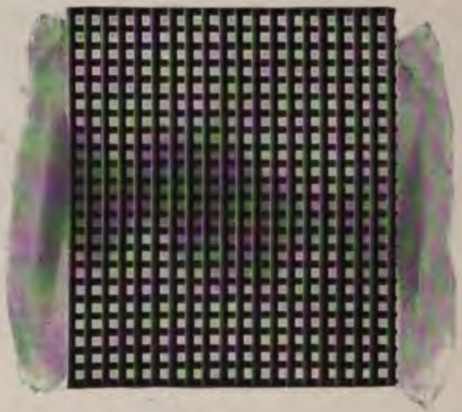


FIG. 86.
Separator for Placing between the Plates of a Storage Cell.

FIG. 87.
Storage Cell Containing the Parts shown in Figs. 84, 85, 86 and 88.
Dayton Electrical Manufacturing Company, Dayton, Ohio.

used with these particular plates is shown in Fig. 86. It is made of hard rubber in one piece and has the general form of a number of bars laid across each other at right angles.

The complete cell is made up of the plates and separators immersed in an electrolyte of dilute acid solution contained in a jar. The electrolyte should completely cover the main portion of the plates, but the terminals and upper portion of the lugs extend above the liquid.

The electrolyte is generally dilute sulphuric acid. The water used with the acid should be very pure, as distilled water.

A complete storage cell having plates and separators like those just described is shown in Fig. 87. The jar is of hard rubber suitable for portable work. It is provided with a cover which is sealed on to make the cell tight, except a small opening, or vent, which is shown between the terminals.

The cover of the cell is shown in section in Fig. 88. The vent is so made that the bubbles of gas, escaping during the charging

Fig. 88.
Cover of Cell shown in Fig. 87.

of the cell and carrying the liquid electrolyte up with them, can escape through the upper part of the vent-plug without carrying the liquid outside of the cell. The conical terminal of one set of plates is shown in the opening through the left-hand end of the cover. This cone is surrounded by a rubber washer and is drawn up tight so as to make a liquid-proof joint.

87. The voltage of a storage cell having lead plates and dilute sulphuric acid electrolyte is about 2.2 volts on open circuit. It drops below the open-circuit value as soon as the external circuit is closed and current flows. The pressure drop is approxi-

mately proportional to the amount of current flowing, for a given cell, when the cell is in good condition. The pressure decreases very slowly during discharge until the battery is almost completely discharged, and then begins to drop very rapidly as the discharge continues.

The voltage is independent of the number of plates in the cell. It is the same when there is only one positive plate and one negative plate, as when there are several of each. In one cell the plates are generally all immersed in the same lot of electrolyte contained in one jar with no partitions to separate one portion of the liquid from another. Exceptions to the last statement are some unusual types of cells with porous jars.

88. The maximum rate of discharge of a storage cell, without injury to the cell, is approximately proportional to the amount of surface area of active material of the electrodes in contact with the liquid electrolyte. If the same size and make of plates are used to make up cells having different numbers of plates in them, then the safe maximum amperage of the cells will be approximately proportional to the number of plates in them. The maximum safe rate of discharge of a cell having 15 plates is about three times as great as that of one having only 5 plates, the plates in both being of the same size and make, as already stated. The rate of discharge is measured in amperes. An excessive rate of discharge is injurious to the cell. It causes the paste to swell and even to drop from the grids.

89. A storage battery is composed of storage cells connected together. Any of the methods of connection that have been given for primary cells can be used for storage cells.

The storage batteries used for ignition purposes are generally made up of two or three cells connected together and inclosed in a case. A battery of this nature does not differ much in appearance from a single cell.

The plates of three storage cells are shown connected together in series in Fig. 89. The two positive plates of the right-hand set are connected by a lead strap to the three negative plates of the middle set. The two positive plates of the middle set are similarly connected to the three negative plates of the left-

FIG. 89.
Connected Plates of a Three-cell Storage Battery.

FIG. 90.
Three-cell Storage Battery with Cover Removed.

hand set. The two threaded bolts at the opposite corners of the entire group are the terminals of the battery.

In Fig. 90 a case containing the three sets of plates and their corresponding jars is shown before the sealing compound is put on the top. The complete battery is shown in Fig. 91. The

Fig. 91.

Complete Three-cell Storage Battery containing Plates shown in Fig. 89.

knurled nuts on the terminals are shown just above the marks "*P+*" and "*N−*."

The voltage of the three cells connected in series is three times that of one cell alone. While the three cells will send more amperes of current through a given external resistance than one cell will, the maximum allowable amperage is the same for the three cells as for one cell alone.

90. "Exide" Storage Battery. — Fig. 92 shows another form of battery that used lead plates and dilute sulphuric acid electrolyte. It is commercially known as the "Exide" battery. One side of both the case and the jar is removed in the illustration,

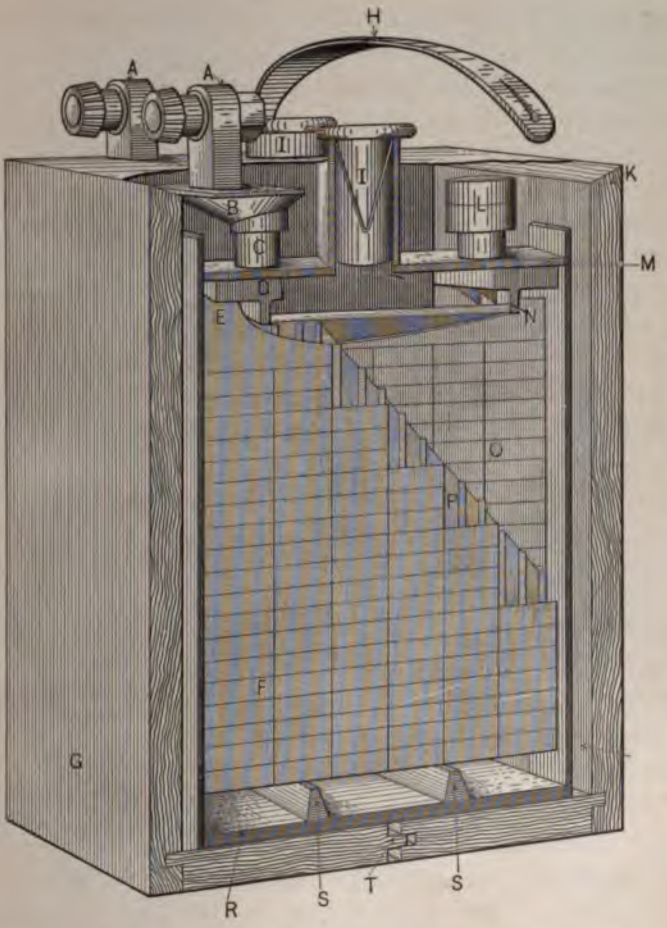


FIG. 92.

Exide Storage Battery. Electric Storage Battery Company, Philadelphia, Pa.

A. Terminals of battery.
B. Inverted petticoat.
C. Pillar post.
D. Plate strap.
E. Lug on plate.
F. Positive plate.
G. Acid-resisting paint.
H. Handle.
I. Vent plugs.
J. Plastic asphaltum.
K. Beveled edge at top of wood case.
L. Connector.
M. Hard rubber cover, sealed in with asphaltum J.
N. Apron. Part of plate strap.
O. Negative plate.
P. Wooden separator.
Q. Acid-resisting compound.
R. Hard rubber cell or jar.
S. Hard rubber ribs.
T. Expansion joint.

and some of the interior members partly broken away to show the construction.

The separator between adjacent positive and negative plates is made of wood chemically treated before using. The chemical treatment of the wood is to remove any substance that might be deleterious to the cell. There are deep vertical grooves in the separator on the side that goes next to the positive plate. These grooves are to allow free circulation of the electrolyte and escape of gas while the cell is being charged. In some forms of this battery a thin sheet of hard rubber with numerous perforations is placed between the positive plate and the grooved side of the separator. The plates rest on high rubber ribs at the bottom of the jar, so that there is ample space left for the sediment which collects at the bottom of the jar. This is important, since the battery is short-circuited internally if the sediment rises high enough to touch the electrodes. An apron *N* on each strap which connects the plates prevents the wooden separators from rising on account of the buoyant action of the liquid. Each vent plug *I* is a hollow cone with a hole near the top to allow the escape of gas from the cell while it is being charged, and a drainage hole at the bottom through the apex of the cone to let the electrolyte flow back into the cell, in case any of the liquid is carried up with the escaping gas.

The binding posts are formed so as to prevent the acid electrolyte from creeping up and spreading over the top of the cell. This prevention is accomplished by forming the lead alloy into the shape of an " inverted petticoat " which is below the binding screw far enough to be covered with the sealing compound of " plastic asphaltum " that covers the top of the battery except the terminals and vents. The edges of the wood case are beveled at the top so that the sealing compound covers them and thus prevents the acid from soaking down into the wood if any of the electrolyte is spilled over the top. The acid is injurious to the wood.

Each grid is cast in one piece and has the form of numerous small horizontal bars held in place by several thin vertical strips. A part section of the grid, made by cutting the plate in two

between two of the vertical strips, is shown in Fig. 93, in which *A* is a side view of part of one of the vertical strips. The small horizontal bars are shown in cross-section at *A*, *B*, *C*, *D*, *E*, and *F*. There are of course a great many more horizontal bars in the entire grid than shown in this section. The exposed surface of each horizontal bar appears as a line, as shown in the preceding figure. The object of making the grid in this form is

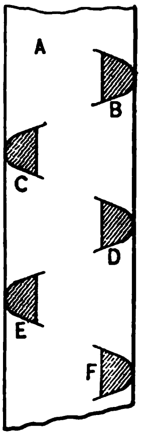


FIG. 93.
Section of Grid for Battery shown in Fig. 92.

FIG. 94.
Phantom View of Exide Storage Battery.

to expose as great a surface of the paste to the electrolyte as possible, and at the same time provide a light-weight grid which holds the paste securely in place.

A phantom view of an Exide battery intended for ignition usage is shown in Fig. 94. This battery is of a slightly earlier form than that shown in Fig. 92, but is the same in a general way, lacking only some of the improvements in detail that appear in the latter form. The battery, Fig. 94, is made up of three cells connected in series. Each of the three cells has three positive plates and four negative ones. Each cell is provided with its own vent plug.

91. Charging the Storage Battery. — A storage battery of the ignition type is generally charged and ready for use when sent

out from the factory. After it has been discharged it can be charged again by connecting to some exterior direct-current source of electric supply and sending current through it in the reverse direction from that in which it discharges. The positive side of the source of supply must be connected to the positive terminal of the storage battery, and the negative of the supply to the negative of the battery. An alternating current cannot be used directly for charging a storage battery, but it can be rectified by suitable apparatus for transforming it into a direct current which can be sent through the battery to charge it.

In charging the battery, as in discharging it, the amount of current must be kept within the maximum safe amperage of the battery. This is ordinarily accomplished by the use of suitable regulating apparatus inserted in the supply circuit. A rheostat is generally used for regulating the amount of current.

Gas is formed in the battery while charging it, slowly at first, and then more rapidly. The formation of gas is especially rapid when the battery has become almost completely charged. (See also Chapter XXVI.)

92. Chemical Action in a Lead Storage Battery. — When a storage cell is in a fully charged condition and ready for use, the active material in the plates connected to the positive terminal is in the chemical form of dioxide of lead (PbO_2) and has a brown color. In the negative plates the active material is in the form of porous, or spongy, metallic lead and has a gray color. Although this has been stated before, it is repeated here to bring it fresh in mind.

During the discharge of the cell, the dioxide of lead in the positive plate is partly changed to monoxide of lead (PbO) by the loss of part of its oxygen. The metallic lead in the negative plate is partly changed into monoxide of lead (PbO) also, by the addition of oxygen to it. The amount of sulphuric acid in the electrolyte is reduced by decomposition into sulphur and water, so that the electrolyte becomes weaker and has a lower specific gravity.

During the charging of the cell the above reactions are reversed and the elements of the cell are restored, more or less completely, to their first-mentioned condition of the charged cell.

93. The capacity of a storage cell is measured in ampere-hours. An ampere of current flowing for one hour is an **ampere-hour.** So is half an ampere flowing for two hours, or four amperes flowing for a quarter of an hour, etc. Four amperes flowing for one hour are four ampere-hours, and the same amount, four amperes, flowing for two hours are eight ampere-hours. In general, the current in amperes, multiplied by the number of hours during which it flows, equals the number of ampere-hours.

Amperes of current × hours of time = ampere-hours.

In order to fully specify a storage battery, its voltage, or the number of cells in it, must be stated in connection with its capacity in ampere-hours. The following table refers to lead storage batteries for ignition use, as made by one manufacturer.

SIZE AND CAPACITY OF IGNITION STORAGE BATTERIES.

All of these batteries are 9 inches high and $6\frac{3}{8}$ inches wide over all.

Number of Cells in Battery.	Volts Pressure. (Approximate.)	Ampere-hours Capacity at Service Rate.	Length over All.	Weight.
			Inches.	Pounds.
1	2	40	$3\frac{7}{8}$	$8\frac{1}{2}$
2	4		$5\frac{11}{16}$	17
3	6		$7\frac{7}{16}$	$25\frac{1}{2}$
4	8		$9\frac{5}{16}$	34
1	2	60	$4\frac{11}{16}$	12
2	4		$7\frac{5}{16}$	24
3	6		$9\frac{15}{16}$	$35\frac{3}{4}$
4	8		$12\frac{9}{16}$	$47\frac{1}{2}$
1	2	80	$5\frac{15}{16}$	$15\frac{1}{2}$
2	4		$8\frac{9}{16}$	$30\frac{3}{4}$
3	6		$11\frac{13}{16}$	46
4	8		$15\frac{1}{16}$	61
1	2	100	$6\frac{15}{16}$	19
2	4		$10\frac{9}{16}$	$37\frac{1}{2}$
3	6		$14\frac{13}{16}$	$55\frac{1}{2}$
4	8		$19\frac{1}{16}$	74

CHAPTER XI.

FLOATING THE STORAGE BATTERY ON THE LINE OF A DIRECT-CURRENT GENERATOR.

94. A storage battery can be kept in continuous service by the method of operating known as " floating the battery on the line." A direct-current generator which will give a voltage somewhat higher than that of the battery is ordinarily used, but modified forms of the system use generators giving a pressure very much higher than that of the battery, sometimes several times that of the battery.

It is assumed in the following discussion that the generator maintains a constant, or nearly constant, voltage slightly higher than that of the storage battery on open circuit when fully charged.

One arrangement of the apparatus for the above method of operation is shown diagrammatically in Fig. 95, in which *A*

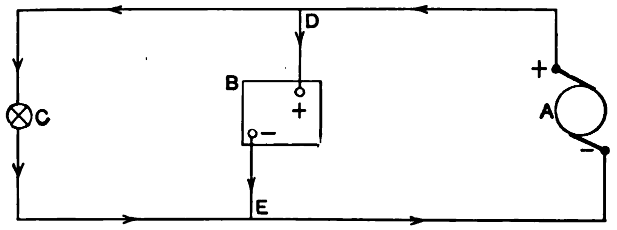


FIG. 95.
Direct-current Generator and a Battery Floated on the Line, with a Light Load.

represents the commutator and brushes of a direct-current generator which maintains a constant voltage, or nearly so; *B* is the storage battery, and *C* is any piece of electrical apparatus, such as an incandescent lamp, through which current is sent. The current flows from the positive (+) brush of the generator to the junction *D*, where it divides, part flowing through the

lamp C and the remainder through the storage battery B in the direction to charge it. These two currents come together again at the junction E and flow through the same wire to the negative (−) brush of the generator A. The direction of the current is indicated by the arrowheads on the lines representing the circuits. This action continues as long as the conditions remain unchanged.

Now suppose that several additional lamps are added to the circuit, as shown in Fig. 96, which are the maximum number that the system is intended to operate. The battery now dis-

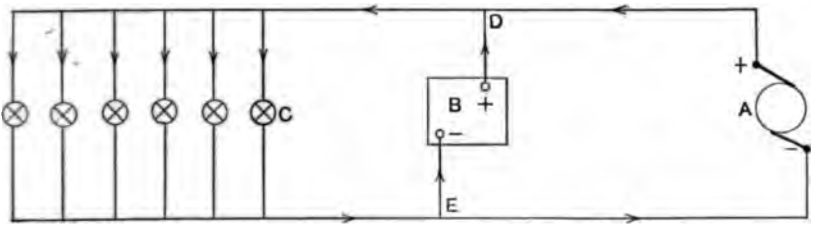


FIG. 96.
Battery Floated on the Line, with Heavy Load.

charges so as to furnish current to the lamps, thus aiding the generator which still supplies current, all of which flows through the lamps. The battery and generator now operate in conjunction, both sending current through the lamps. The generator delivers more current when all of the lamps are in the circuit than when only one is in the circuit. If all of the six lamps are alike, they will take about six times as much current as any one of them alone.

The greater number of lamps requiring more current than one, lowers the voltage at the lamps and also the difference of pressure at the junction points D and E. When the difference of pressure between D and E drops to a lower value than the voltage of the storage battery on open circuit, the battery begins to deliver current instead of receiving it, as in the case where only one lamp was in circuit. The lowering of the pressure between D and E, due to increasing the number of lamps, causes the generator to deliver more current.

Another method of arranging the apparatus is shown in Fig. 97 for one lamp, and in Fig. 98 for several lamps. The operation of this system is in a general way the same as that of the preceding two figures. The direction of current is indicated by the arrowheads on the circuits.

If the circuit is broken between the generator and other apparatus, the generator will of course become inoperative so

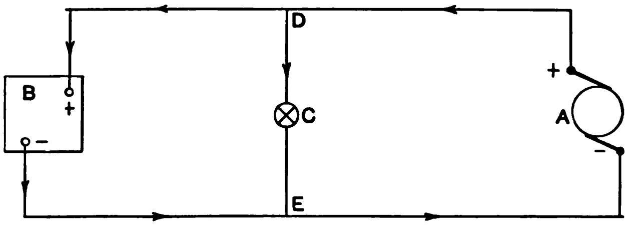


FIG. 97.
Modified Form of Fig. 95.

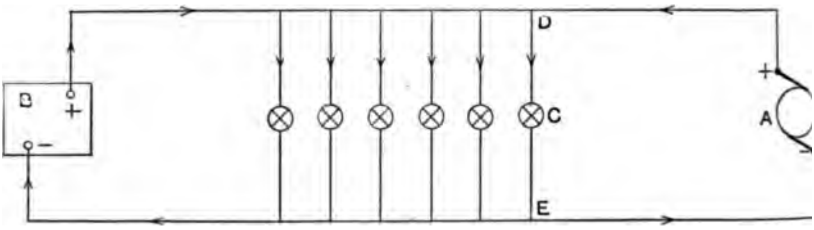


FIG. 98.
Modification of Fig. 96.

far as the other parts of the system are concerned. The battery will then furnish all of the current required for the lights. This within the limits of the battery.

Still another method of arrangement is shown in Fig. 99. The dynamo *A* is placed between the storage battery *B* and the load *C*. When the load is small, as represented by one lamp *C*, and the generator is at its proper voltage, it sends current through both the storage battery to charge it and through the lamp. The current from the generator divides at *D*, part going to the lamp and part to the positive side of the storage battery, as indicated

by the arrowheads. These divided currents unite again at E and flow together to the negative brush of the generator. If the full load is put on, as represented by several lamps in Fig. 100, then the storage battery discharges into the circuit, thus aiding the generator. Both send current through the lamps. The direction of the current is indicated by the arrowheads. The two currents unite at D and flow together through the lamps.

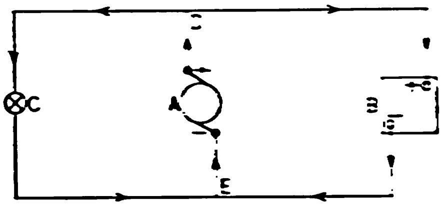


FIG. 99.
Electric Generator between the Load and the Battery which is Floated on the Line. Light Load.

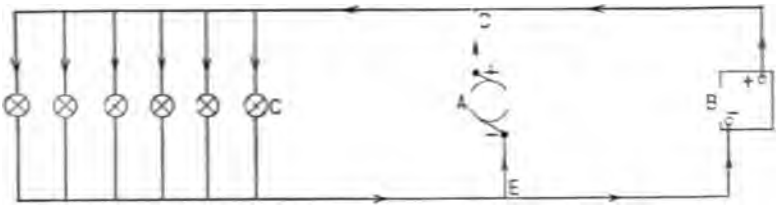


FIG. 100.
Electric Generator between Heavy Load and a Battery, which is Floated on the Line.

They then separate at E, part going to the negative brush of the generator and the remainder to the negative side of the battery.

95. An automatic cut-out is used on some storage-battery and generator systems in which the storage battery is floated on the line. This has been mentioned in connections with Figs. 63 and 64. The purpose of this cut-out is to prevent the flow of a large reverse current from the battery through the generator in case the latter slows down so as not to give a sufficiently high voltage, or in case of its complete stoppage. It is often desirable,

and especially so for ignition service where the motor runs intermittently, to have the cut-out also operate automatically to put the generator into circuit when its speed is again sufficient to give the necessary voltage.

An electric system with an automatic cut-out of the last-mentioned type is shown diagrammatically in Fig. 101. The cut-out consists of an electromagnet with a double winding and an armature with a contact-point at one end. The cut-out armature as shown consists of a blade spring to which is fastened a contact point and a soft steel disk, the latter opposite the end of the magnet core. One end of the blade spring is fastened to a

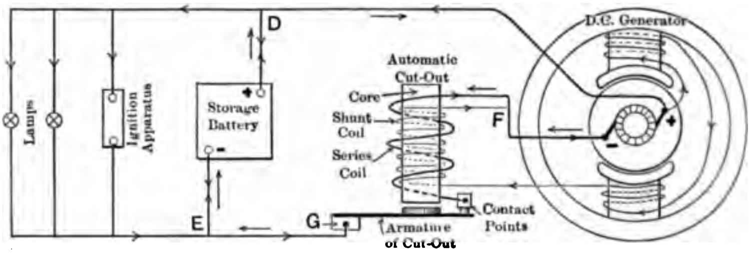


FIG. 101.

Complete Dynamo and Storage-battery System with an Automatic Cut-Out.

stationary block *G* in such a way that the elastic action of the spring tends to draw the armature away from the core and separate the contact-points. When the core is magnetized it attracts the cut-out armature and holds it in the position shown with its contact-point pressed against the mating contact-point to which is connected one end of one of the magnetizing coils of the cut-out. If the magnetism of the cut-out core becomes weak, the armature then springs away from it so as to separate the contact-points.

One coil of the cut-out is permanently connected in series with the field-magnet coils of the shunt-wound generator. This coil, marked "shunt-coil" in the figure, has a comparatively great number of turns of insulated wire large enough to continuously carry the current that flows through the field-coils of the generator. The other coil of the cut-out, marked "series-coil," is in series with the main circuit of the generator. This coil has com-

paratively few turns of insulated wire large enough to carry all of the current from the generator.

When the system is operating in the regular manner, the current flows through the circuits in the direction indicated by the arrowheads on the lines representing the circuits. Since the direction of flow in the two lines leading from the storage battery to the points *D* and *E* may be first in one direction and then in the other, it is indicated by a pair of opposed arrowheads on each line. The currents in both coils of the cut-out flow in the same direction around the core, and both magnetize the core in the same direction so as to keep the contact-point of the cut-out armature drawn up against its mate.

If the generator slows down so that its voltage drops below that of the battery, then the battery sends current back to the generator and through it and the cut-out coils. This back current flows from the positive (+) terminal of the battery to *D* and then to the positive (+) brush of the generator, where it divides, part flowing through the field-coils of the generator and the shunt-coil of the cut-out in the same direction as before to the junction *F*. The remainder of the back current flows through the armature of the generator to the negative (−) brush and thence to *F*. From *F* all of the back current flows through the series-coil of the cut-out in the opposite direction from that in which it flowed before. The direction of the back current through the main circuit is indicated by the arrows alongside the circuit.

The back current through the series-coil of the cut-out opposes the magnetizing action of the current in the shunt-coil and demagnetizes the core of the cut-out enough to allow the cut-out armature to spring back so as to separate the contact-points. The current through the series-coil stops as soon as the circuit is opened by the separation of the contact-points. A weak current continues in the shunt-coil as long as the generator keeps running at slow speed. This current ceases as soon as the generator stops running. There is then no current in any part of the system to the right of the points *D* and *E*. The battery keeps sending current continuously through the part of the system to the left of it.

If the generator is started again, the contact-points of the cut-out still remaining apart, it will at first send current through only its field-coils and the shunt-coil of the cut-out, including of course the generator armature and the connections of this circuit. When the voltage at the brushes of the generator becomes somewhat higher than that of the battery as the speed increases, the current sent through the shunt-coil is great enough to magnetize the core sufficiently to draw the cut-out armature toward it and thus close the circuit at the contact-points. This establishes the normal condition of operation.

The size of the cut-out as shown in the figure is much larger in proportion to the other apparatus than it is in the constructed apparatus. It is shown large in order to make its construction appear plainly.

A compound-wound direct-current generator can also be used with a cut-out of this nature.

In Fig. 102 a storage battery is floated on the line of a variable-speed direct-current dynamo. A volt-ammeter is included in

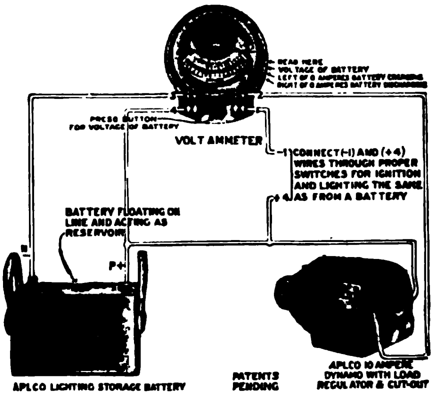


FIG. 102.

APLCO Electric System with Battery Floated on the Line. Apple Electric Company, Dayton, Ohio.

the system, for measuring the voltage of the battery and the amount of current flowing through the battery.

The hand, or pointer, of the volt-ammeter is shown pointing to the zero of the scales on the dial. When the dynamo is send-

ing current through the storage battery to charge it, the indicator hand moves to the left and points to the lower scale, which gives the reading of the amount of charging current. When the battery is discharging, the indicator hand moves to the right of the zero and indicates the current rate of discharge. To obtain the voltage of the battery, the push-button ("press-button") must be pressed in. The indicator hand then points to the pressure on the upper scale. The current through the battery is indicated continuously except during the time the button is pressed in to obtain the reading of the voltage.

The dynamo is provided with an automatic cut-out and a load regulator. The latter regulates the current delivered by the dynamo within a limited range. It does this by automatically varying the resistance in the field-coil circuit. The load regulator makes it possible to drive the armature of the dynamo at a rotative speed proportional to that of the crank-shaft of the motor, even when the speed of the crank-shaft is extremely variable, as in automobile and boat motors, and still keep the current from the generator approximately constant as long as the armature rotates fast enough to generate sufficient voltage. The automatic cut-out opens the dynamo circuit when the speed of the armature falls below the requisite amount.

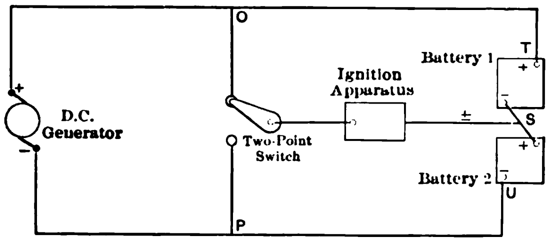


FIG. 103.
Two-voltage System with Two Storage Batteries Floated on the Line.

96. A two-voltage system with two storage batteries floated on the line is shown in Fig. 103. Two storage batteries of the same voltage are connected in series between the positive and negative sides of the circuit in the same manner as the one

storage battery in Figs. 99 and 100. This system gives two voltages, one double the other when the two storage batteries are of the same voltage, as stated.

A two-point switch in the ignition circuit can be closed on either of the two contact-points by placing the pivoted arm in the corresponding position.

The flow of current through the system depends on the amount of electrical resistance of the ignition apparatus relative to the voltage of the storage batteries. The resistance of the ignition apparatus is ordinarily low enough for the method of operation to be as follows:

When the voltage of the dynamo brushes is higher than that of the storage batteries in series, as measured between the points T and U, and the switch is closed as shown, then while the circuit is closed in the ignition apparatus, the current from the positive brush of the dynamo flows to O, then through the switch and ignition apparatus to S, thence through battery 2 and to the negative brush of the dynamo. At the same time current flows from the positive terminal T of battery 1 to O, then through the switch and ignition apparatus to S, and thence to the negative terminal of battery 1. While the circuit is broken in the ignition apparatus in the usual manner of operation, the dynamo sends all of its current to T and through both storage batteries in series so as to charge them. If the dynamo stops and is cut out of circuit, then battery 1 supplies the current to the ignition apparatus, and battery 2 is idle.

When the switch is closed as shown, and the voltage at the dynamo brushes is higher than that of the two batteries in series, then battery 2 continuously receives charging current, and battery 1 is alternately discharged and charged in accordance with the closed and open positions of the ignition apparatus. When the switch is closed on its other contact-point, the battery 2 is alternately discharged and charged, and battery 1 is continuously charged.

97. A two-voltage system with lamps and ignition apparatus is shown in Fig. 104. The voltage at the lamps is approximately twice that at the ignition-apparatus terminals. At the lamps

the voltage is approximately equal to that of both batteries in series; at the ignition apparatus the voltage is approximately equal to that of one battery. If there were no loss of voltage

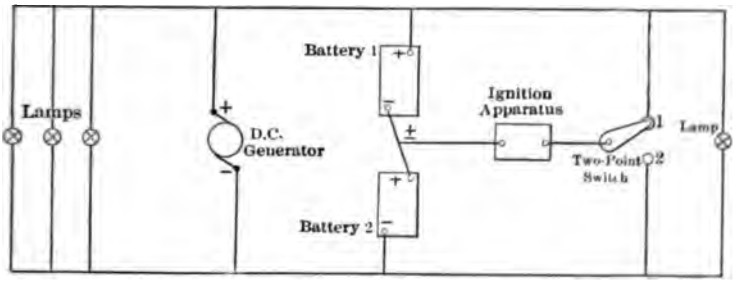


FIG. 104.
Two-voltage System with Lamps and Ignition Appliances.

in the connecting wires, the voltage at the lamps would be the same as that of the two batteries in series; and that at the ignition apparatus would be equal to that of one storage battery.

The manner of operation of this system is essentially the same as that of Fig. 103.

98. A switchboard for a two-voltage system, a direct-current dynamo, and two storage batteries are connected together in Fig. 105. The switchboard has an ammeter for indicating the amount of current, and a voltmeter for measuring the pressure of the system. There is also a pilot lamp which glows while its circuit is closed by pressing the push-button at the left hand side of the board. The voltmeter is made to register by pressing the push-button at the right-hand side of the board. The operation of the system is essentially the same as that of Figs. 103 and 104.

The board has five switches, all of the blade, or knife, type, whose handles are shown at 1, 2, 3, 4, and 5.

When the double-pole double-throw switch 1 is closed on the dynamo side of the switchboard, as shown, the dynamo sends current through both storage batteries in series to charge them, and at the same time supplies current to the 12-volt lamp circuits. Opening the switch breaks both the armature circuit of the

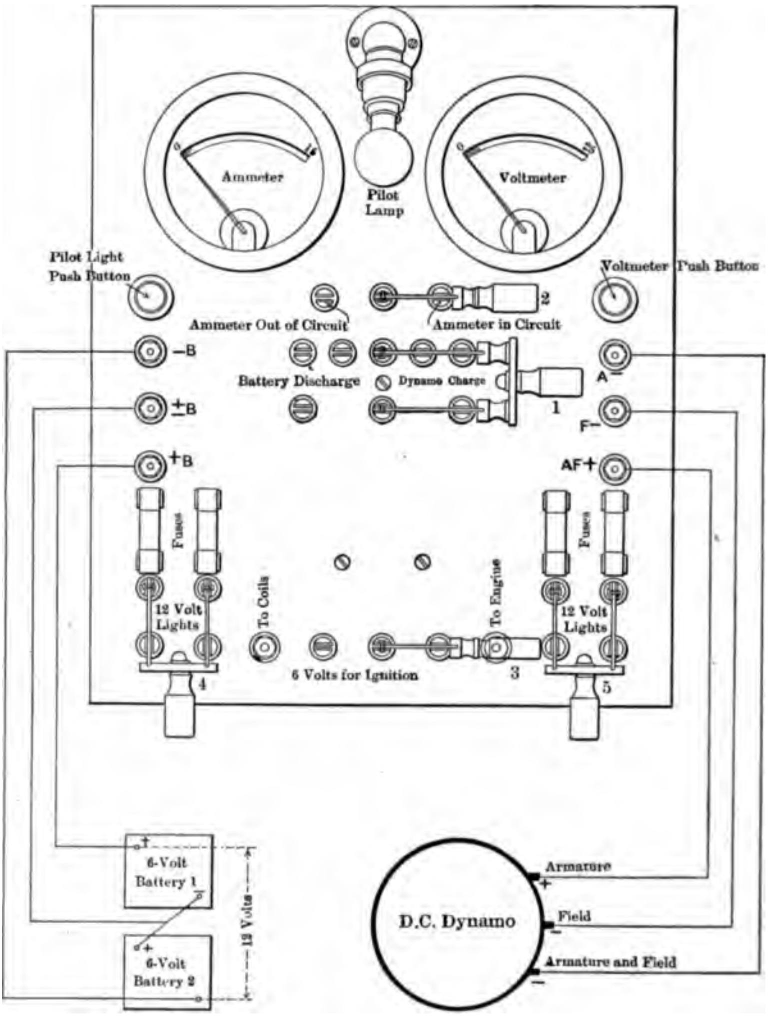


FIG. 105. (*See also* Figs. 106 and 107.)
Switchboard Apparatus and Connections.

dynamo and its field-circuit, and also breaks the battery circuit to the 12-volt lamps. When the switch is closed in its left-hand position, the battery discharges through the 12-volt circuits if the lamps are turned on. The connections to the ignition circuit are not affected by opening or reversing the main switch 1.

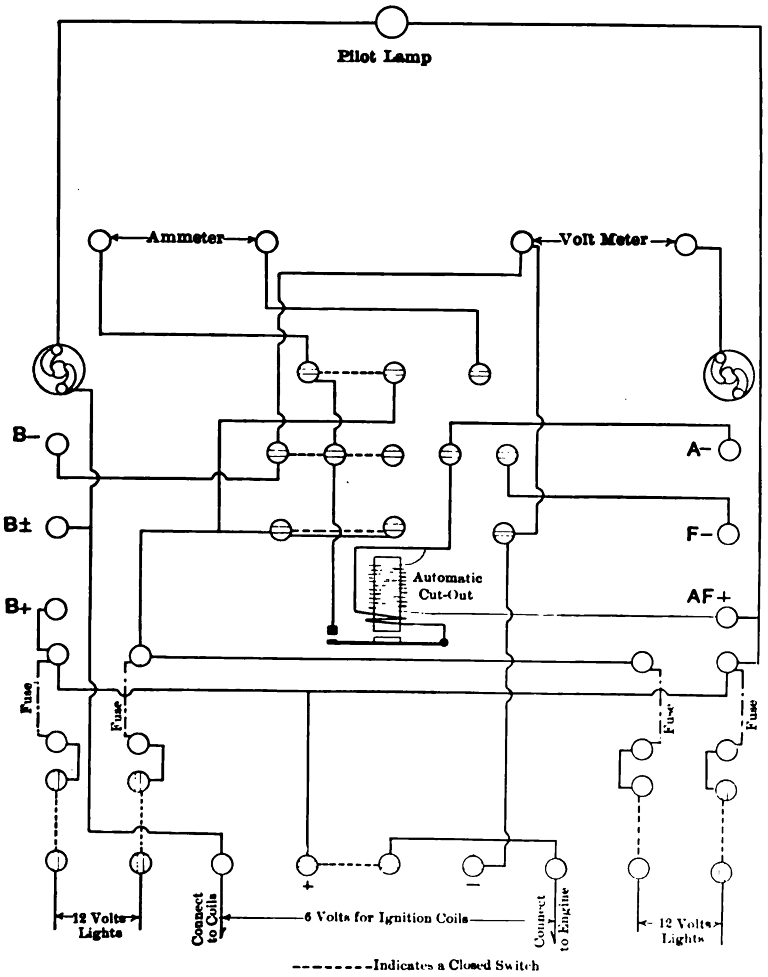


FIG. 106. (*See also* Figs. 105 and 107.)
Wiring Diagram showing Connections at the Back of the Switchboard.

The single-pole double-throw switch 2 is for cutting the ammeter into or out of circuit. The ammeter is in circuit when this switch is in the position shown. Opening this switch breaks either the main circuit of the dynamo or the battery-discharge circuit, according to the position of the main switch 1.

The single-pole double-throw switch 3 is for reversing the

direction of the 6-volt current through the ignition apparatus. When the switch is in the right-hand position, as shown, the ignition apparatus takes current from battery 2 if the main switch is closed in the battery-discharge position. If the ignition switch 3 is closed in its left-hand position, then battery 1 supplies current to the ignition apparatus.

The single-throw switches 4 and 5 are for opening and closing the lamp circuits.

The wiring diagram of the switchboard is shown in Fig. 106, which also shows the automatic cut-out for protecting the dy-

FIG. 107. (*See also* Figs. 105 and 106.)

Dynamo, Storage Battery and Switchboard. Dayton Electrical Manufacturing Company, Dayton, Ohio.

namo. The switch-blades are represented by broken lines. The double-throw switches are represented as closed in the reverse positions of the preceding figure. The diagram shows the ignition apparatus connected to the positive side of battery 1. The ammeter is out of circuit, and both the main circuit and the field circuit of the dynamo are open.

Fig. 107 is a photographic illustration of the dynamo, switchboard, and two 6-volt storage batteries such as are used in a system of the nature just described. It is suitable for ignition and lights on a small boat.

CHAPTER XII.

MECHANICALLY OPERATED MAKE-AND-BREAK IGNITERS AND KICK-COILS FOR LOW-TENSION IGNITION.

99. A mechanically operated igniter in the form of a low-tension ignition plug is shown in Fig. 108 together with the means of operating it. The illustration is elementary in its

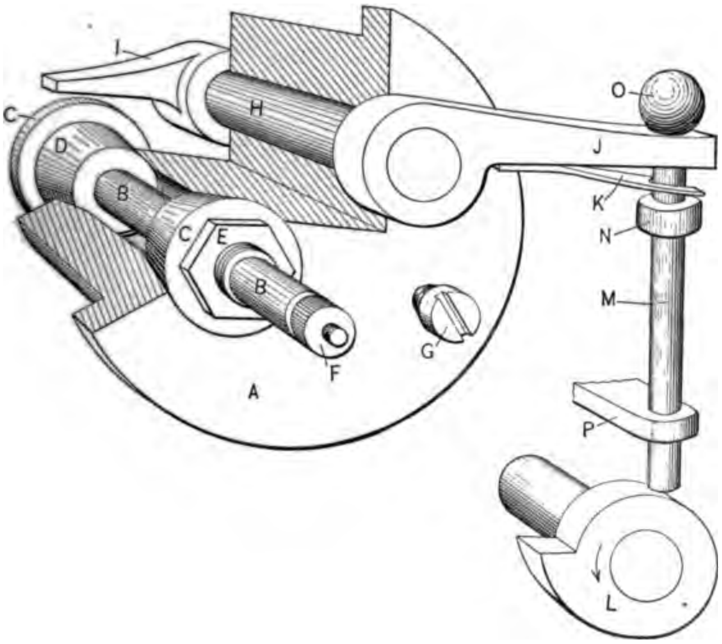


FIG. 108.
Make-and-break Igniter or Spark-Plug. Elementary Form.

nature. Part of the metal plug *A* is cut away to show the construction. The front end of the igniter remains outside of the cylinder of the motor when the igniter is in place, and the back end either projects into the combustion chamber or forms part of its wall.

A metal rod *B* extends through the plug and is enlarged at the inner end as shown at *C*. The hole through which this bar passes is considerably larger than the bar and is coned at the ends to fit correspondingly shaped insulators *C* and *D*, which hold the rod in place and insulate it from the plug *A*. When the nut *E* is screwed down it draws the insulating cones *C* and *D* into the taper ends of the hole in the plug so as to make a gas-tight joint, and suitable packing around the rod next to the enlarged inner end and under the nut makes tight joints at these points.

A knurled nut *F* at the outer end of the insulated electrode *B* affords a means to attach the wire or other form of electric conductor which brings the current to the plug. The screw *G* can be used for attaching the other wire when it is desired to bring both sides of the electric circuit to the igniter in this manner. The more general practice is to connect one side of the circuit to the metal of the motor at the most convenient point. The metallic contact between the plug and the motor metal gives electric connection also between them.

A movable spindle *H* fits in another hole through the plug so as to have metallic contact with the plug, and at the same time be free to rotate, or rock, in the body of the plug. The inner end of the spindle has a metal arm *I* rigidly attached to it. This arm is sometimes called the movable electrode. Another rocker-arm *J* is fastened rigidly to the outer end of the spindle *H*. A blade-spring *K* is fastened to the rocker-arm *J* at the end next the spindle *H* and is of such a form that its free end stands away from the arm when the spring is not stressed. This completes the igniter proper.

When the outer arm *J* is raised it rocks the inner arm *I* down so that it makes contact with the inner end *C* of the insulated electrode *B* and thus closes the electric circuit between the insulated electrode and body *A* of the plug. Then when the arm *J* is moved downward so as to separate the movable electrode from contact with the insulated electrode, an electric arc is drawn between the electrodes *C* and *I* at the point where the contact is broken.

The means for operating the igniter consist, as shown, of a cam *L* and a cam-follower *M*. The latter is in the form of a push-rod with a collar *N* and an enlarged spherical upper end *O*. The push-rod passes freely through suitable openings in the ends of the arm *J* and spring *K*. The spring presses lightly downward against the collar when the parts are in the position shown. The guide *P* is for keeping the push-rod in position. The cam is driven by the shaft on which it is mounted.

As the cam *L* rotates in the direction indicated by the arrow on it, the projecting lobe of the cam lifts the push-rod *M* and then allows it to drop when the edge of the lobe passes from under the push-rod. This occurs when the cam has passed through about three-quarters of a revolution from the position in which it is shown.

The upper movement of the push-rod first lifts the rocker-arm *J* so as to bring the movable electrode *I* down against the stationary electrode. The movement of the rocker-arm is stopped as soon as the movable electrode makes contact with the stationary one. The continued upward movement of the push-rod bends the spring *K* and the rod slips up through the arm so that the enlarged end *O* rises above the arm. When the edge of the cam passes from under the push-rod, the reaction of the spring snaps the push-rod down quickly so that the knob on the upper end strikes the rocker-arm a sharp blow and drives its free end downward so as to cause a rapid separation of the electrodes. This is known as the **hammer-break** method of interrupting the electric current.

The rapid separation of the contact-points of the igniter is very essential to the successful operation of the igniter. Compared with slow separation of the contact-points, the rapid separation produces a better arc for ignition and causes less fusing, or burning, of the contact-points.

The insulation used in the igniter is generally either mica or steatite (soapstone). The mica should be pure and especially free from any metallic substance or metallic compounds. When steatite is used, it is generally first machined to form and then baked at a high temperature to bring it to the condition in which it is commonly used for the tips of gas burners.

The contact-pieces (points) of the igniter are generally made of either platinum, an alloy of platinum and iridium (platino-iridium), of steel alloy, especially a steel alloy containing a large proportion of nickel together with less amounts of other elements. While platinum and its alloys are excellent for the purpose, they are extremely expensive. Only small pieces are set into the electrodes, and are generally removable.

100. The duration of contact between the electrodes of a mechanically operated igniter should be as short as possible to establish current flow to the necessary amount when the source of electricity supply is a battery. Long duration of contact is wasteful of electricity and soon exhausts the battery. On the other extreme, when an alternating-current generator supplies the electricity in the usual manner, the electrodes may be kept in contact continuously except during the time necessary to separate them to form the arc and to close them again immediately, so far as current supply is concerned. When electricity is supplied by a direct-current generator, it is generally advisable to have a short period of contact, since imperfect contact maintained for some time may cause fusing of the electrodes.

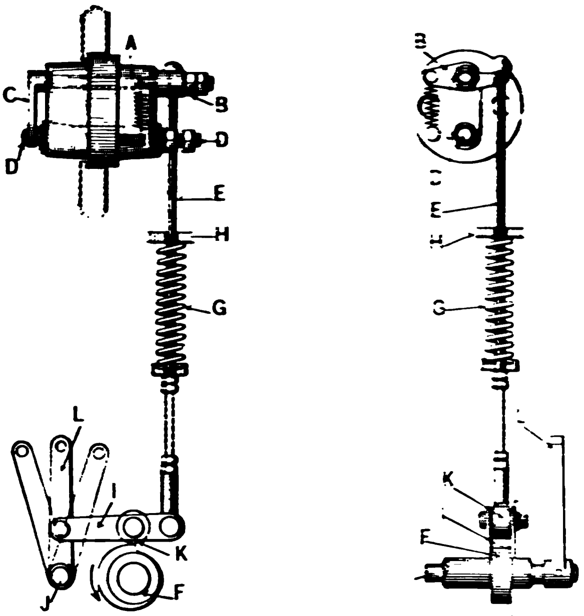
Other conditions, such as the use of several igniters in the different combustion chambers of a motor with several cylinders, may make a short period of contact necessary. It is generally undesirable to have the electric circuit closed through two or more mechanically operated igniters in different combustion chambers at the same instant. In some ignition systems it is impossible to operate when two igniters in different combustion chambers have their electrodes in contact at the same instant.

101. Bosch Mechanically Operated Igniter.— Fig. 109 shows two views of an igniter and operating mechanism as constructed by the Bosch Magneto Company. The side of the igniter is shown in (*a*), and the external end in (*b*).

A coiled tension-spring *A* acts on one end of the external rocker-arm *B* so as to press the movable electrode *C* against the stationary electrode *D* when the operating rod *E* is lifted by the cam *F*. The operating rod *E* is pressed downward by a coiled compression spring *G*, whose lower end bears against a collar on

the rod and whose upper end bears against the stationary support *H*.

As the cam *F* rotates it lifts the operating rod *E* against the resistance of the compression spring so as to first allow the coiled tension spring *A* to pull the contact-point of the movable electrode against the stationary one, and then to push the rod up still farther so that it slips through the hole in the external rocker-arm. The enlarged upper end of the rod is thus lifted



(*a*) (*b*)

FIG. 109.

Bosch Make-and-break Igniter. Bosch Magneto Company, New York City.

free from the rocker-arm. As the cam lobe passes from under the cam follower, the operating rod *E* is forced downward by the expansive action of the compression spring *G*, and the ball at the top of the rod strikes the external rocker-arm and moves it down so as to quickly separate the contact-points of the electrodes. The compression spring *G* is made strong enough to overcome the resistance of the tension spring *A* and keep the

cam follower in continuous contact with the cam during the highest speed at which the igniter is to be used in any particular application.

The lower end of the operating rod *E* is pin-connected to one end of each of a pair of links *I* whose opposite ends are similarly connected to a short rocker-arm on the shaft *J*. These links carry the roller *K* which bears against the cam and follows its outline. The short rocker-arm just mentioned can be rocked by a control lever *L* fastened to the same shaft. The shaft *J* of the controller and the cam shaft are supported by bearings which are maintained in fixed positions relative to the igniter plug.

The control lever *L* is used to vary the instant of separation of the contact-points of the electrodes relative to the rotative position of the cam and to the position of the piston of the motor in its movement; in other words, to advance the ignition by causing it to occur earlier in the revolution of the cam, or to retard it by causing it to occur later. The ignition is advanced by moving the control lever to the right, and retarded by moving it to the left. The dotted outline of the control lever to the right is its position for early ignition, and the dotted outline at the left is its position for late ignition.

102. Truscott Boat Manufacturing Company's Igniter. — This igniter is used especially in motor boats. It is shown in Fig. 110. The outer end of the stationary insulated electrode appears at *A*. This electrode extends through the plug in the usual manner and projects inward near the end of the movable electrode *B*, which is fastened to a rotative spindle whose outer end is shown at *C*. A hammer-break arm *D* fits freely rotatable on the spindle *C* and is normally pressed against a stop on the spindle by a coiled torsion spring *E*. One end of *E* is fastened to a taper pin which passes through the rocker-shaft.

When ignition is to occur, the free end of the rocker-arm *D* is raised by the lifter *G*, which is bored to fit freely rotatable on the end of the push-rod *H*. As the arm *D* is lifted it rocks the spindle *C* and contact arm *B* with it until the contact-point in *B* strikes against the stationary electrode. This prevents

further movement of both the rocker-arm *B* and the spindle *C*, but the hammer-break arm *D* is lifted still higher and turns on the spindle *C* so as to separate itself from the stop on the spindle. The lifting of *D* winds up the spring *E* to a slight extent more than it is normally. The lifter-arm *H* continues rising till it disengages from *D*. The spring *E* then snaps the hammer-break

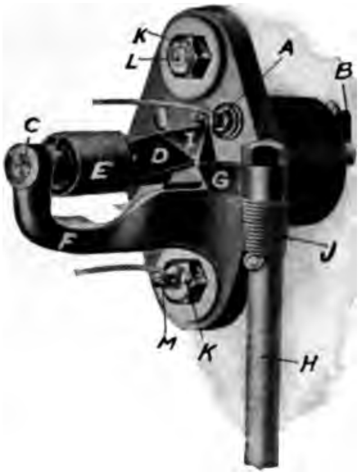


FIG. 110.

Make-and-break Igniter. Truscott Boat Manufacturing Company, St. Joseph, Michigan.

arm *D* down quickly so that it strikes a sharp blow against the stop on the spindle *C* and causes rapid separation of the ignition points. The downward movement of *D* continues till it strikes the arm *F* and is stopped in a horizontal position.

The lifter-rod *H* then descends, carrying with it the lifter *G*, and the end of *G* strikes against the bevel *I* on *D*. The end of *G* is also beveled where it strikes the bevel *I*. The action of the bevel twists *G* around on *H* as they descend, so that *G* slips down past *D* and is then snapped back under *D* by the coiled tension spring *J* so that the lifter *G* is again brought into position to lift *D*.

K and *K* are nuts on the stud-bolts *L* and *M* for fastening the igniter to the motor. The lower stud-bolt *M* is extended outward

and serves as a binding-post for holding one of the wires of the external circuit.

Fig. 111 shows the mechanism for operating the push-rod. This is accomplished by an eccentric *N* on the crank-shaft *O* of

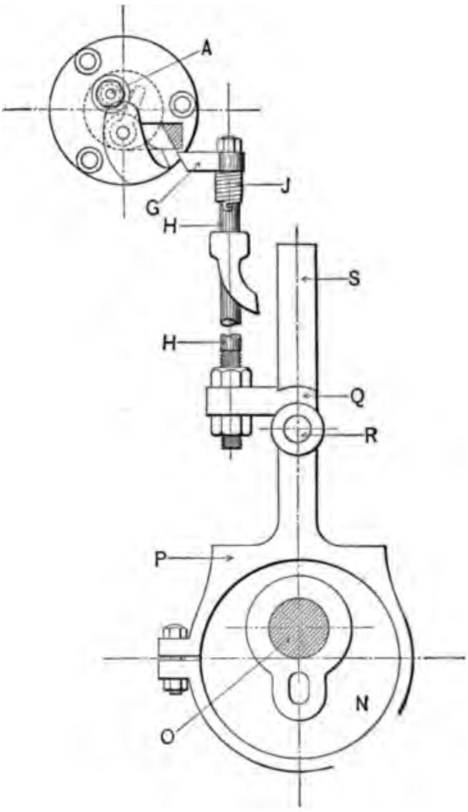


FIG. 111.
Operating Mechanism of Fig. 110.

the motor. The eccentric strap *P* is connected to the member *Q* by the pin *R*. The member *Q* is fastened to the lower end of the push-rod *H* and is limited to vertical movement by the plunger *S* which fits in a suitable guide. The eccentric has a free rotative fit on the crank-shaft and is connected to the arms of a fly-ball governor (not shown) also mounted on the crank-

shaft. The eccentric is thus caused to rotate with the crank-shaft so as to move the push-rod, but its angular position on the crank-shaft is changed by the action of the governor as the speed of rotation varies. This shifting of the eccentric varies the time of ignition so that it occurs earlier at high speeds of rotation than at slow speed. When the motor stops, the governor brings the eccentric to a position such that ignition cannot occur before the crank of the motor has passed its dead-center position just after compression of the combustible charge. This prevents ignition at such an instant as to drive the crank-shaft of the motor backward when starting it.

103. The Fay & Bowen low-tension igniter, Fig. 112, has an adjustable hammer-break device as part of the igniter. Both

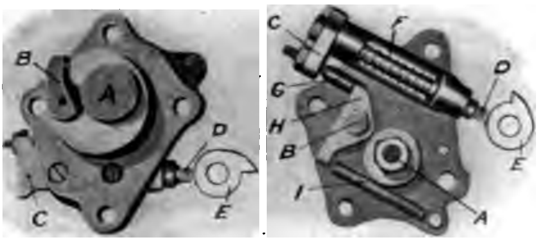


FIG. 112.
Fay & Bowen Make-and-break Igniter.

the stationary electrode *A* and the movable electrode *B* are provided with inserted contact-pieces, or points. The hammer for breaking the circuit comprises a head *C* and a rod, or plunger, *D*. The latter slides through holes in the outer end of the body of the igniter, and is pressed against the cam *E* by a coiled compression spring *F* which is wound around the plunger and bears against a collar on it. The head of the hammer has an adjustable striking piece *G* which is pressed against the external arm *H* of the movable electrode so that the contact-points of the electrode are kept apart except while the plunger is pushed back.

When the plunger is pushed back by the rotating cam *E*, the coiled tension spring *I* draws the contact-point of the movable

electrode against the contact-point of the stationary electrode. The tension spring I is connected to one end of the external arm H of the movable electrode. The cam forces the hammer back far enough to remove its striking piece to some distance from the arm H. When the edge of the rotating cam passes out of engagement with the plunger, the hammer, including the plunger, is snapped down by the spring F and the striking piece hits the arm H so as to drive it around and separate the contact-points of the electrodes quickly.

104. Westinghouse make-and-break igniters are shown in Fig. 113. One is right-hand and the other left-hand. The mica

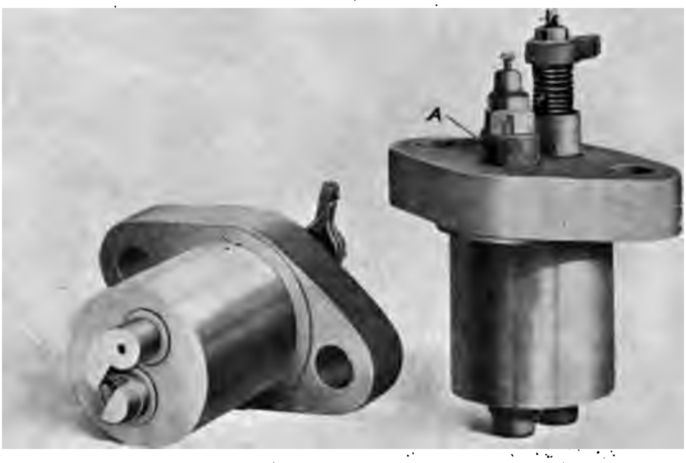


FIG. 113.
Low-tension Igniter of the Westinghouse Machine Company, Pittsburg, Pa.

washers for insulating the stationary electrode at the outer end are visible at A. The inner end of the plug is recessed to receive similar insulation. The contact-points of the electrodes are pressed together by a coiled torsion spring wound around the rocker-spindle of the movable electrode and pressing against the outer rocker-arm. These plugs have removable contact-points in the electrodes.

105. The Snow Steam Pump Works mechanically operated make-and-break igniter for low-tension current is shown in Fig. 114. The cast-iron plug 1 has the metal cut away in the middle portion to secure lightness and ease of construction. A flange at the outer end serves as a means of supporting some of the external parts and for fastening the plug to the engine.

The movable electrode 2 is of high-grade nickel steel and is one piece with the inner rocker-arm 8 which carries the removable contact-point 9. The inner end of the spindle rocks in a stationary bronze bushing 15, and the outer end is provided with a tight-fitting bronze sleeve 17 which rocks in a steel bushing 16. The external rocker-arm is fastened to the spindle by a bolt-and-nut lock.

The stationary electrode 3 is insulated from the plug by mica washers 4 and 5, and lava bushings 6 and 7. It is held in place by nuts 12 and 13, which also hold the terminal 11 into whose shank is soldered the wire for bringing electricity to the electrode. A removable contact-point is set into its inner end.

Two oil pipes 20 connect the outer end of the plug with oil passages leading to the inner bronze bushing 15. These oil passages are shown most clearly in the "section on B-B."

A threaded hole 22 through the flange of the plug is for the insertion of a cap-screw, or a set-screw, which can be screwed down to press its point against the metal of the engine and thus forcibly withdraw the plug from the engine to a short distance after the fastenings have been removed.

The outer ends of two of these igniters with all attached parts are shown in Fig. 115. The reference numbers in this figure are not the same as in the preceding one.

106. The mechanical make-and-break operating mechanism of the Snow Steam Pump Works for a pair of igniters in the same combustion chamber is shown in Fig. 115. The igniters are like the one shown in the preceding figure.

The head of the upper igniter is shown at 1, and that of the lower one at 2. The ends of the insulated stationary electrodes of the two igniters are at 3 and 4, and the wire terminals for the electric conductors are shown in place fastened to these elec-

FIG. 114. (*See also* Fig. 115.)

Low-tension Igniter. Mechanical Make-and-Break. For Large Engine. The Snow Steam Pump Works, Buffalo, N. Y.

1. Body of plug; cast-iron.
2. Movable electrode; steel, not insulated.
3. Insulated stationary electrode, steel.
4, 5. Mica washers for insulating stationary electrode.
6, 7. Lava insulating bushings.
8. Inner rocker-arm; integral part of rocker-shaft 2.
9. Contact-point; movable and removable.
10. Contact-point; stationary, removable.
11. Terminal to which electric conductor (wire) is soldered.
12, 13. Nuts for fastening stationary electrode and terminal in place.
14. External rocker-arm end. Shown better in Fig. 115 as parts 5 and 6.
15. Bushing for rocker-arm bearing; stationary, bronze.
16. Bushing for rocker-arm bearings; stationary, steel.
17. Sleeve, tight on 2, loose in 14; bronze.
18. Oil hole.
19. Groove for oil pipe.
20. Oil pipe leading to inside bearing of rocker shaft.
21. Stud-bolt and nut for fastening igniter to engine. Two used.
22. Threaded hole in flange of plug. For bolt to start (loosen) the plug to remove it from the engine.

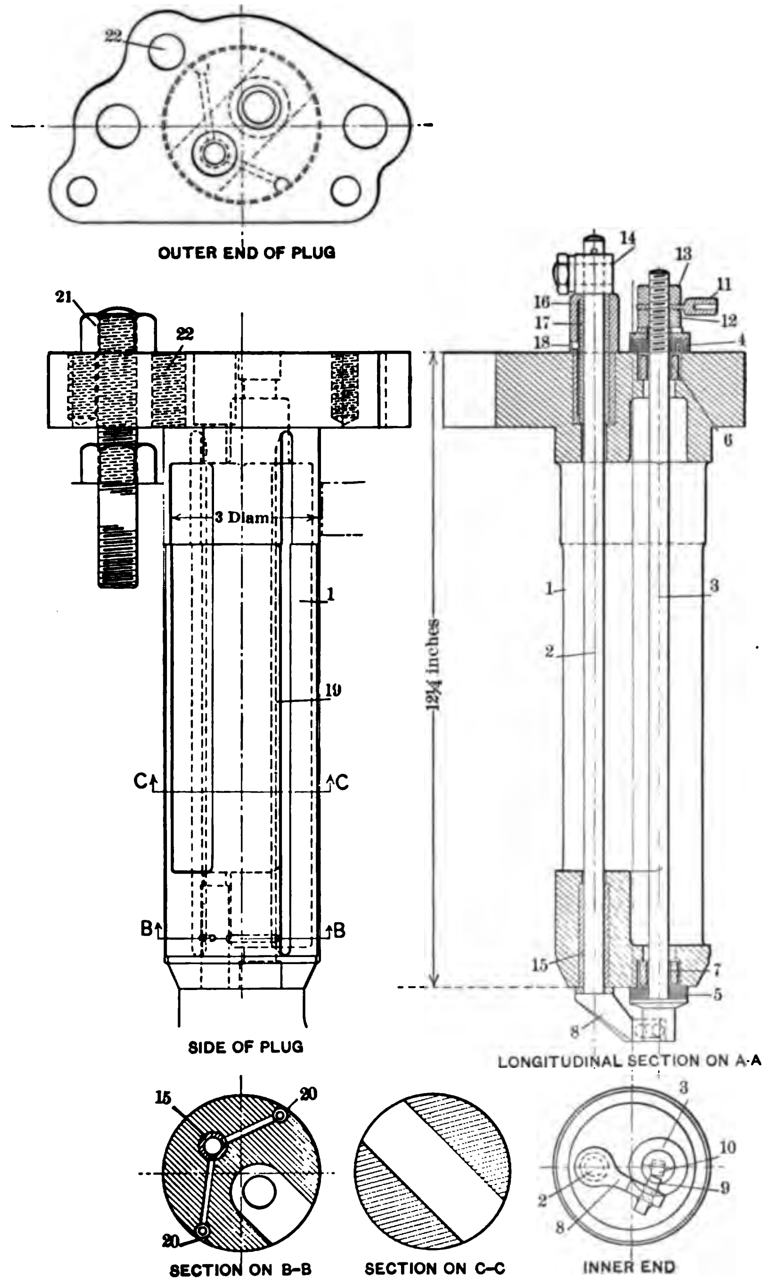

22
OUTER END OF PLUG
21
22
3 Diam.
1
19
C
C
B
B
SIDE OF PLUG
14
13
11
16
17
12
18
4
6
1
3
2
12¾ inches
15
7
5
8
LONGITUDINAL SECTION ON A-A
15
20
20
SECTION ON B-B
SECTION ON C-C
3
10
9
2
8
INNER END

FIG. 114.

trodes by nuts. The external rocker-arms, or tappet-arms, 5 and 6 are in positions which they have when the contact-points of the electrodes are touching each other. The contact-points and inner rocker-arms are represented by broken lines. The coiled tension springs, 7 for the upper igniter and 8 for the lower one, connected to the external rocker-arms, are for bringing the contact-points of the movable electrodes against the stationary contact-points.

The cam-shaft 9 has fastened to it a cam-lobe 10, which pushes back the cam-follower, or push-rod, 11, as the cam rotates in the direction of the arrow on the cam-shaft. The push-rod is connected to the tappet-rod 13 by means of the pin 20. The tappet-rod is pin-connected to the rocker-links 16 and 17, which swing on stationary shafts 18 and 19 respectively. The pin 20 makes the connection to 17, and a similar pin connects the tappet-rod to the link 16.

As the push-rod 11 is forced back against the resistance of the coiled compression spring 21 by the action of the cam, the tappets 14 and 15 are moved away from the tappet-arms 5 and 6. Then when the cam-lobe passes out of engagement with the push-rod, the latter is forced quickly toward the left by the spring 21. The tappet-rod and tappets follow the same movement, and the tappets strike the arms 5 and 6, thus causing rapid separation of the contact-points of the electrodes. The push-rod and attached parts continue their movement toward the left till the buffer 25 strikes the stop-block 22. The push-rod is kept in its position farthest toward the left by the action of the spring 21, with the buffer pressed against the stop-block, until the cam again forces the push-rod back for another ignition. The contact-points of the electrodes are thus kept separated and the electric circuit broken at them except during the time the cam pushes the rod back as far and farther than the position in which the push-rod is shown.

The time of ignition can be adjusted by means of the parts 26 to 30 inclusive. The ignition is advanced by rotating the hand-wheel 26 so as to run the screw farther into the nut 27. This movement of the hand-wheel forces the block 29 against

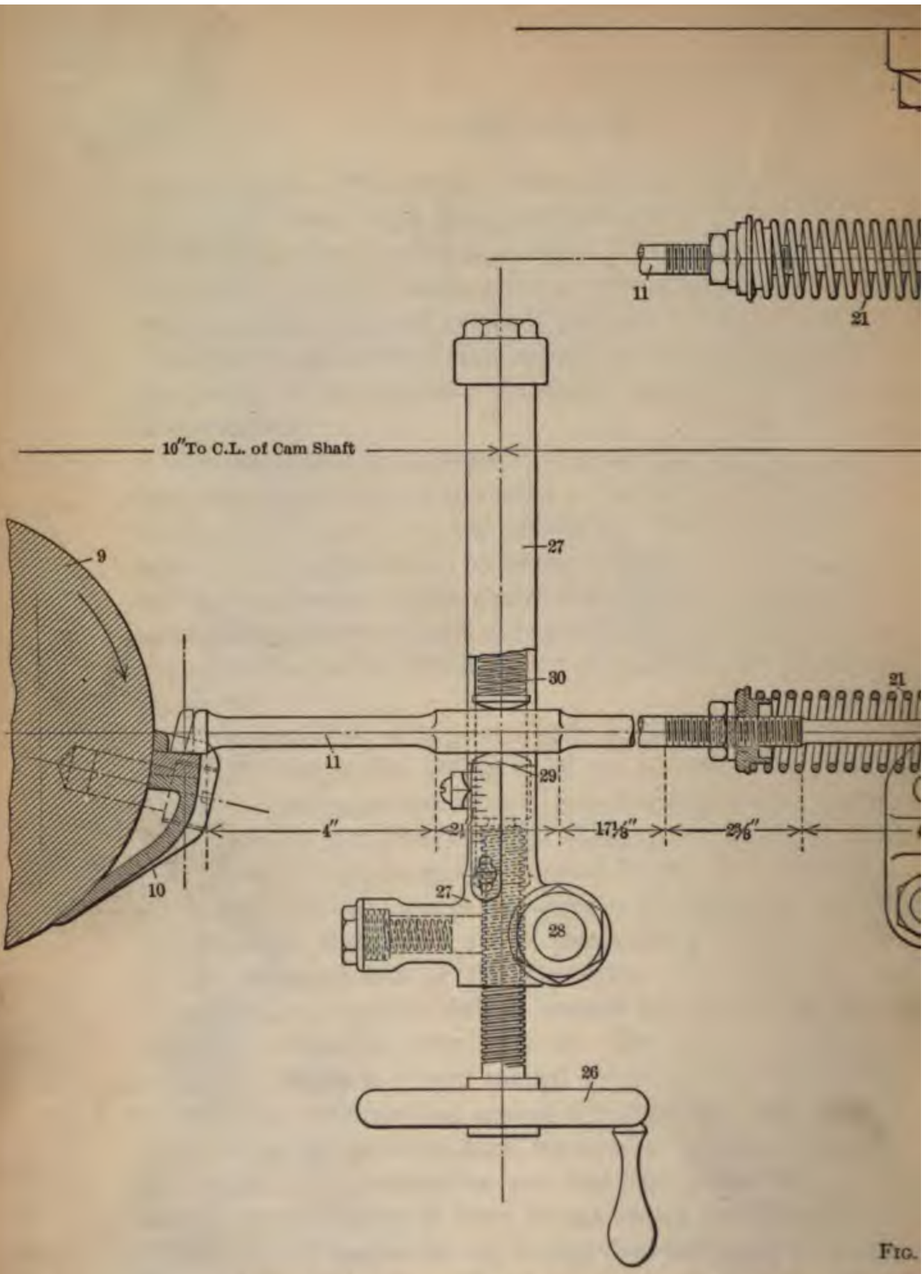
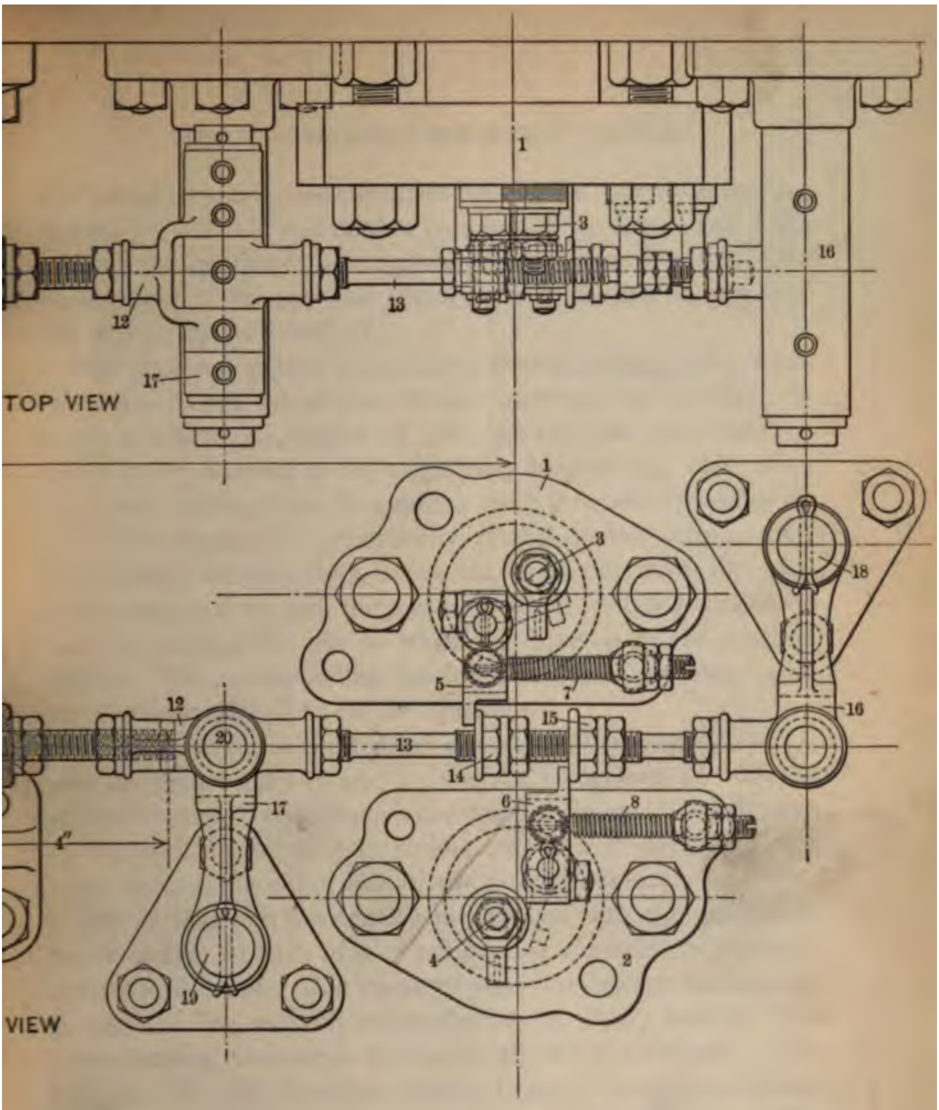


FIG.

Operating Mechanism for Make-and-break Igniter. Two Igniters Arm

1. Outer end of upper igniter plug.
2. Outer end of lower igniter plug.
3. Insulated stationary electrode of upper igniter.
4. Insulated stationary electrode of lower igniter.
5. External rocker-arm of upper igniter.
6. External rocker-arm of lower igniter.
7, 8. Coiled tension springs for drawing contact-points of electrodes together.
. *Cam-shaft or lay-shaft.*
. *Cam-lobe for operating* the pair of igniters.
11. *Cam follower,* or push-rod; extends up to the yoke 12.
12. Yoke on upper en
13. Tappet rod, pin-
16 and 17.
14, 15. Flanged tappe
5 and 6.
16, 17. Upper and lo
18, 19. Stationary sh
20. Pin for connectin
21. Coiled compressio
22. Stop-block for st
shaft.



114.)

rated by One Push-Rod. The Snow Steam Pump Works, Buffalo, N. Y.

12 and the rocker-links

the igniter rocker-links

ionary shafts 18 and 19.
inks 16 and 17.

h-rod 11 toward cam 10.
ush-rod *11 toward cam-*

23. Bracket for holding stop-block 22.
24. Guide, flanged at right-hand end.
25. Four leather washers between flange on guide 24 and steel washer next to 22.
26. Hand-wheel and screw for adjusting time of ignition.
27. Adjusting nut and spring sleeve; held by stud 28.
28. Stud for supporting 27; stationary.
29. Block at end of adjusting screw.
30. *Coiled compression spring for holding push-rod 11 against 29.*

the push-rod and moves the latter toward the coiled compression spring 30, which is still further compressed by this action. Retarding the ignition is accomplished by a reverse rotation of the hand-wheel. The nut and spring-tube 27 is held in place by the stationary stud-bolt 28.

The push-rod swings about the pin 20 as a hinge-joint when the rod is moved sidewise to advance or retard the ignition. In order to allow this motion of the push-rod, the stop-block 22 must move sidewise in its supporting bracket 23. The stop-block has a sliding fit on the guide 24 which is fastened to the push-rod. The bracket is cylindrically curved on the surfaces that bear against the stop-block to prevent its moving in the direction of the length of the rod, the center of curvature being coincident with the axis of the pin 20 when the latter is in the position shown. The corresponding bearing surfaces of the stop-block are similarly curved to fit the bracket.

The portion of the mechanism consisting of the tappet-rod 13, and the rocker-links 16 and 17, may be recognized as "Watt's parallel motion," which causes the point at the middle of the axis of the push-rod to move in almost exactly a straight line for a short distance on either side of the position shown.

107. A four-unit low-tension mechanism with one make-and-break igniter for each of four combustion chambers is shown in outline in Fig. 116. The insulated stationary electrodes are 1, 2, 3, and 4. The movable electrodes are *A*, *B*, *C*, and *D*. The corresponding cams are *a*, *b*, *c*, and *d*, all on the same shaft. The full line *GH* with branches leading to each insulated electrode represents the electric conductors for carrying current to the insulated electrodes. The broken line with branches to each rocker-spindle of the movable electrodes is to indicate that all of these electrodes are electrically connected together by the metal of the motor, or otherwise.

The cams are fixed on the cam-shaft at equal angles with each other so as to operate the igniters at regular intervals relative to the rotation of the cam-shaft. As shown, electrodes *A* and 1 are in contact with each other. The order of action of the igniters, given by the numbers of the insulated electrodes, is 1, 3,

4, 2 when the cams are fastened to the cam-shaft in the position shown.

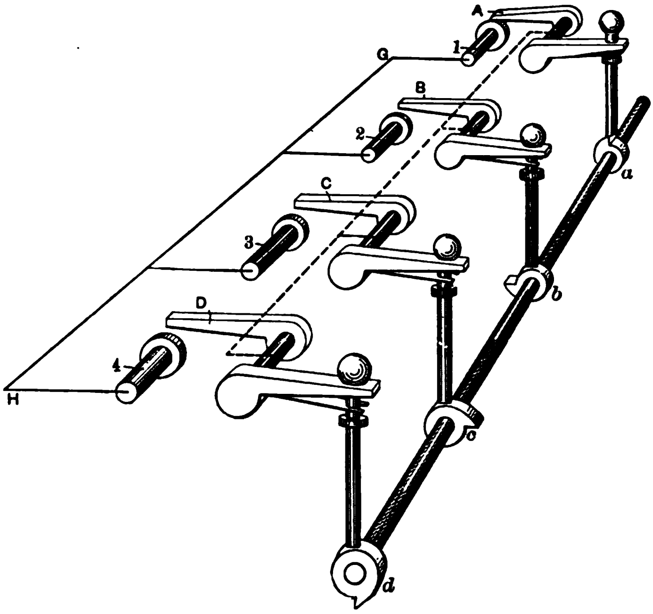


FIG. 116.
Make-and-break Igniters Arranged for Four Combustion Chambers.

108. An Allis-Chalmers gas engine with mechanical make-and-break low-tension igniters is shown in Fig. 117, reproduced from a photograph of the engine. The four igniters are at 1, 2, 3, and 4. The cam-shaft 5 lies parallel to the stroke of the pistons and carries four cams, one for each igniter. It is driven by screw-gears and a cross-shaft in the casing 6. Advance and retard of ignition is effected by moving one of the screw-gears along its shaft so as to change the relative rotative positions of the driving and driven shafts. The hand-wheel 7 is for shifting the screw-gear to adjust the ignition as described.

Kick-Coils.

109. A single-wound kick-coil, also called reactance coil and spark-coil in combustion-motor practice, is used in connection

FIG. 117.

Gas Engine with Mechanically Operated Low-tension Igniters. Allis-Chalmers Company, Milwaukee, Wis.

with low-tension mechanical make-and-break ignition systems in order to obtain a good electric arc between the contact-points of the igniter when current is supplied by a battery, also, under some conditions, when current is supplied by a dynamo.

A kick-coil consists essentially of a coil of insulated copper wire wound in several layers around a bundle, or sheaf, of small wires of mild steel or soft iron. Fig. 118 shows one form of kick-coil.

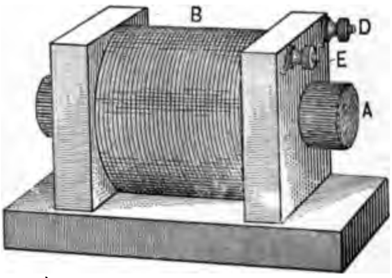


FIG. 118.
Kick-Coil with the Ends of the Core Exposed.

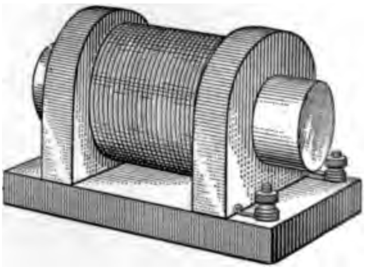


FIG. 119.
Kick-Coil with Protective Cap over Ends of Core.

A is the core of small wires of soft iron or mild steel, and *B* is the coil of insulated copper wire. The core and wire are mounted on a wooden frame *C*. The ends of the insulated copper wire of the coil are connected to binding posts *D* and *E*, which are the terminals of the coil. The kick-coil is neither more nor less than an electromagnet, but it takes the names just given above on account of the use to which it is applied.

Fig. 119 is another kick-coil in which the ends of the core are covered with non-magnetic caps to prevent rusting.

Other forms of mountings for kick-coils are shown in Figs. 120 and 121. In the latter the coil is inclosed in a water-tight casing.

The sizes of the kick-coils found in use vary considerably, those for very large engines being larger than those for small ones. The average size is about 6 inches long over all, with a core from $1\frac{1}{8}$ to $1\frac{1}{4}$ inches diameter, and with a coil from 3 to $3\frac{1}{2}$ inches long containing from 5 to 6 pounds of insulated copper wire, including the weight of the insulation on the wire. The insulation on the wire is generally a double covering of cotton

thread such as is ordinarily used for insulating magnet wires. The diameter of the copper wire is generally that corresponding to No. 14 American wire gauge (.064 inch), or somewhat larger. The electrical resistance of the coil is generally in the neighborhood of one ohm. These dimensions apply to coils such as are

FIG. 120.
Kick-Coil. Ordinary Type.

FIG. 121.
Kick-Coil Inclosed in Waterproof Casing.

used with small stationary engines. Kick-coils longer in proportion to the dimensions just given are sometimes used, but they are not as efficient as the shorter ones of equal weight and electric resistance.

The kick-coils intended for use in damp places, as on open boats, generally have the insulation on the wires saturated with waterproof insulating varnish put on by a process which removes moisture from the covering wrapped on the wires.

110. Screw-top Kick-Coil. A kick-coil with a screw top is shown in Fig. 122. The threaded top of the coil can be screwed into a plate such as is sometimes used for a battery (see Fig. 82). The size of the coil, $2\frac{1}{2}$ by $6\frac{3}{16}$ inches, is practically the same as that of a standard dry cell. It can therefore be put into the screw-plate along with dry cells, occupying the same amount of space as one of the cells. The coil is also provided with the usual form of terminals and nuts, so that wires can be connected to it in the usual manner.

FIG. 122.
Screw-top Kick-Coil to go in Battery Case with Dry Cells. Stanley & Patterson, New York, N. Y.

111. Tell-tale Kick-Coil. — A kick-coil with a tell-tale for visibly indicating the action of an igniter is shown in Fig. 123, in both side and end views. The **tell-tale** consists of a piece of mild steel *A* suspended by a short bar *B* which swings on the pin *C* that passes through the upper end of the bar and a bracket *D*. The latter is fastened rigidly to one of the caps of the kick-coil.

When no current is passing through the kick-coil, the tell-tale hangs in the position shown in the figure. As soon as current sufficiently large for contact ignition passes through the coil, the part *A* is quickly drawn toward the core of the coil by magnetic action. The tell-tale falls back again quickly when the current is interrupted, as by the separation of the contact-

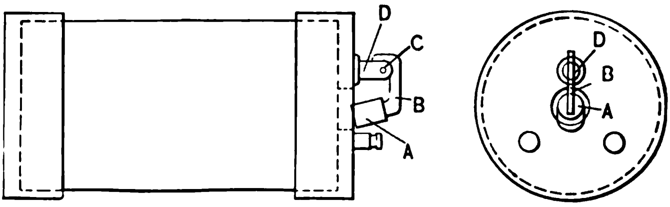


FIG. 123.
Tell-tale Kick-Coil.

points of the igniter. The kick-coil is placed in series with the igniter when used in a make-and-break ignition system.

If any trouble prevents the igniter from closing the circuit so that the necessary amount of current flows for satisfactory ignition, then the action of the indicator is sluggish as it is drawn toward the coil core if some small amount of current flows. If no current flows through the igniter, the tell-tale has no motion. The indicator falls back sluggishly if the breaking of the circuit is not accomplished quickly, as it should be at the igniter contact-points.

The tell-tale is therefore an indicator of whether the igniter is operating effectively, improperly, or not at all.

CHAPTER XIII.

MECHANICAL MAKE-AND-BREAK LOW-TENSION IGNITION SYSTEMS.

112. A battery, a reactance coil, and a make-and-break igniter of the mechanically operated type are electrically connected together in Fig. 124 so as to form a low-tension ignition system. All of the parts are represented conventionally. Only the electrodes of the igniter are shown. It is immaterial whether the battery is considered a primary battery or a storage battery, so far as the principle of operation of the system is concerned.

The positive (+) terminal of the battery is connected to one of the terminals of the kick-coil, and the other terminal of the coil is connected to the insulated electrode *S* of the igniter. The negative (−) terminal of the battery is electrically connected

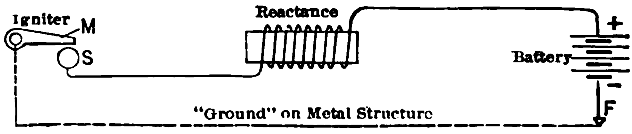


FIG. 124.

Elementary Low-tension Make-and-break Ignition System with Battery Current.

to the movable electrode *M* of the igniter. As shown in the diagram, the negative wire from the battery is connected at *F* to some part of the metal structure which forms part of the engine or of the metal frame to which the metal of the engine is metallically, and therefore electrically, connected. The metal structure is customarily referred to as **ground.** The negative side of the battery may, if desired, be connected by a wire direct to the igniter. Diagrams in which the metal structure is used as part of the electric circuit involve all of the features of those in which the frame is not used as part of the electric circuit, and, in many cases, several additional features.

As soon as the electrodes make contact with each other so as to close the electric circuit, current begins to flow from the positive (+) side of the battery through the kick-coil (reactance coil), the igniter, and then through ground back to the negative side of the battery. When the electrodes are separated to break the electric circuit, an electric arc is formed between the contact-points momentarily at the instant of separation. This arc will ignite a combustible mixture of gases.

The reactance coil is placed in the circuit in order to secure a sufficiently strong arc with a small current from a battery of low voltage. The pressure at the battery terminals is generally not more than six volts. The current seldom exceeds five amperes and is often less than two amperes. It is probably usually between one and two amperes. With this pressure and current, only a very minute arc, or spark, can be obtained without the aid of a reactance coil.

The stronger arc obtained with the reactance coil in circuit is due to the inductive action of the coil. Breaking the circuit at the igniter causes an immediate decrease in the current. The magnetic strength of the core of the reactance coil decreases in consequence of the decrease of current in the winding of the coil. This decrease of magnetism in the core reacts to prevent rapid decrease of current in the winding. The decrease of current in each turn of the coil also reacts inductively to prevent rapid decrease of current in the other turns of the winding. The total effect of the reactance coil is to cause the current to flow longer, both in time and distance, across the gap formed between the electrodes by separating them than when no reactance coil is used.

Although no switch for opening and closing the circuit by hand is shown in the diagram, one can be put in at any convenient point.

113. The duration of contact between the electrodes of the igniter should be as short as possible with satisfactory operation when a battery supplies the current. This in order to secure economy of current and long life of the battery. The circuit must be kept closed long enough, however, to allow the current to become sufficiently strong to make a good arc when the elec-

trodes are separated. The reactance coil prevents the current from reaching its full strength as quickly as it would if there were no reactance in the circuit. The coil prevents rapid increase of current as well as rapid decrease.

114. A magneto and a make-and-break igniter are connected together as parts of a low-tension ignition system in Fig. 125.

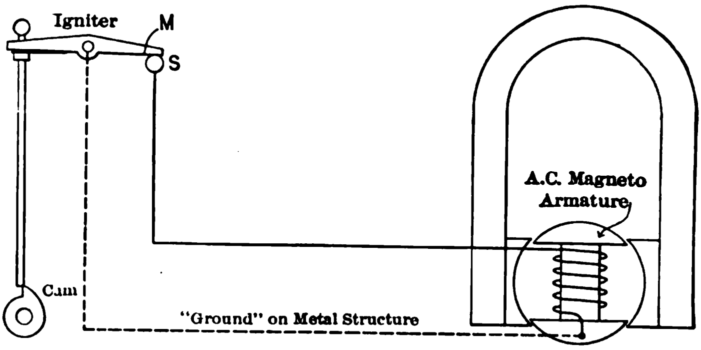


FIG. 125.
Elementary Make-and-break Low-tension Alternating-current Magneto Ignition System.

The magneto is of the shuttle-wound alternating-current type, and the igniter is mechanically operated. The operating mechanism is of the type shown in Fig. 108.

The insulated end of the armature winding of the magneto is electrically connected to the insulated electrode *S* of the igniter by a wire. This is the only connection necessary between them if the frame or base-plate of the magneto is set on a metallic structure which has metallic (electric) connection with the igniter. If the magneto is mounted on a non-metallic base which is not a conductor of electricity, then electric connection between the magneto and the metal structure or the igniter must be provided.

The magnets and pole-pieces of the magneto should not have contact with or be very close to a piece of iron or steel, such as part of the frame of the motor. It is generally best to have no iron or steel connection whatever between the magnets and an iron or steel part of the structure on which the magneto is

mounted. The base of the magneto, or the straps or other form of fastening for attaching the magneto to a steel structure, can be of any non-magnetic metal or alloy. Brass, bronze, and aluminum alloy are commonly used for this purpose.

Low-tension alternating-current magnetos intended for ignition usage generally have only one terminal for making external connection. In case there are two terminals, one can be connected to the metal structure (ground) or to the igniter direct, and the other to the insulated electrode of the igniter in the usual manner. The latter has been described.

The igniter must operate in synchronism with the production of maximum electromotive force, or pressure, in the magneto, since a suitable arc can be formed only when there is sufficient pressure to cause a flow of current large enough to produce an arc of the desired strength. If the magneto armature rotates, and a one-lobe cam such as is shown in the figure is used to operate the igniter, then the cam may rotate at twice the speed of the armature, so as to draw an electric arc at each half-revolution of the magneto armature, which is as frequently as an arc can be drawn when the magneto is of the type shown. Or the cam may rotate at the same speed as the armature, so that an arc is drawn at every second production of maximum pressure in the magneto.

It is customary to have a one-lobe cam make either two, one, or one-half revolution for each revolution of the magneto armature when the magneto produces two impulses per revolution of its armature. This applies to a magneto of the type shown in the figure. If a magneto which gives four impulses per revolution of its rotor is used, then the one-lobe cam may make either four, two or one revolution per revolution of the magneto rotor.

It is not necessary, on account of economy of current, to limit the time during which the circuit is closed by keeping the electrodes of the igniter in contact with each other when current is supplied by an alternating-current magneto, since the magneto does not supply current continuously and there is no need of securing economy of current.

No reactance coil is required in connection with an alternating-current magneto. The armature of the magneto acts as a reactance to produce a strong arc at the ignition points. A switch can be placed at any convenient point in the circuit for opening the circuit to stop ignition, or a switch between ground and the wire leading to the igniter may be closed to stop ignition.

115. A direct-current generator, a kick-coil, and a mechanical make-and-break igniter are connected together for a low-tension

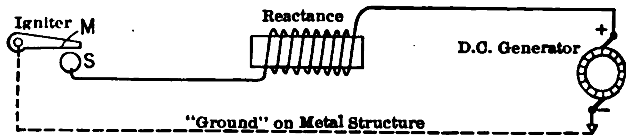


FIG. 126.

Elementary Make-and-break Ignition System with Direct-current Generator.

ignition system in Fig. 126. The generator is represented only by its commutator and brushes.

The positive brush of the generator is connected to one terminal of the reactance coil, and the other terminal of the coil is connected to the insulated electrode *S*. The negative brush of the generator is connected to the metallic ground of the structure. This system is the same as that in Fig. 124 except the use of a direct-current generator instead of a battery, and the same statements apply regarding the manner in which connections may be made.

A generator giving a pressure of five volts and having a capacity of five amperes is suitable for this system. The current capacity may be even less than five amperes. The field-magnets of the generator may be either permanent magnets or electromagnets. If of the latter type, they may be either plain shunt-wound or compound-wound. The shunt-wound type is less expensive to construct and is entirely satisfactory. Either of the electromagnetic types requires some time to pick up its magnetism after starting, and is therefore not very convenient to use in connection with an isolated motor which must be de-

pended on to drive the ignition generator, unless a battery is provided for ignition while starting the motor.

Direct-current generators do not always have enough inductive action to be used without a reactance in the circuit. A hand-switch may be put in the circuit where desired.

116. System for Four Combustion Chambers. Mechanical Make-and-break Igniter, Storage Battery, Primary Battery, and Direct-current Generator. — Fig. 127 shows connections for four low-tension igniters, one for each of four combustion chambers, to which current can be supplied either by a direct-current generator, a primary battery, or a storage battery, using only

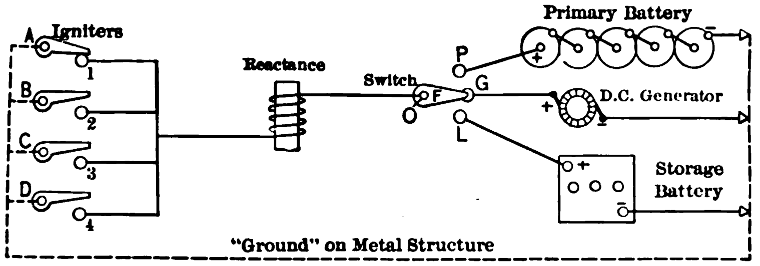


FIG. 127.
Make-and-break Ignition System for Four Combustion Chambers and Having Three Sources of Current Supply.

one at a time. This system is applicable to a four-cylinder single-acting motor, or to a double-acting engine with two cylinders.

The switch-arm *F* is pivoted at *O* and its free end can be moved into position to bear against either of the contact-points *G*, *L*, or *P* of the switch. The arm is shown in the position to use the generator. The switch-points *G*, *P*, and *L* should be far enough apart to keep the arm from making contact with two of them at the same time while shifting it from one point to another.

It is immaterial whether the positive or the negative sides of the generator and batteries are connected to the switch, but it is advisable to have either all of the positive or all of the negative terminals connected to it, since there is then less chance of

injury to the batteries in case electric connection is accidentally made between the switch-points, or if the insulation of the switch becomes poor so that leakage of current may occur. If *G* were connected to the positive of the generator and *L* to the negative of the storage battery, then if *G* and *L* were electrically connected together an excessive current would flow through the generator and storage battery in series. The path of this current would be through the connections to the switch-points *G* and *L*, and the ground connections of the generator and storage battery. Little or no current would flow through the igniters, and there would be no ignition in consequence. A similar, but less severe, action would occur if the positive of the generator were connected to the negative of the primary battery, or the positive of the storage battery to the negative of the primary battery.

The storage battery is not floated on the line, and therefore must be charged from some separate source of current supply. The generator shown might be used to charge the storage battery by connecting them together properly with a suitable rheostat or other current-regulating device in the circuit.

An electric arc can be obtained at only one of the igniters at a time. If two igniters are closed and then one opened, no arc will be formed between the electrodes during their separation. This system can be extended to any number of igniters, provided only one igniter has its electrodes in contact at any instant.

117. An alternating-current magneto, a primary battery, and four mechanical make-and-break igniters are used in the low-tension system of Fig. 128. When the switch is closed on its contact-point *L* as shown, current is furnished by the magneto only. The battery and the reactance coil are both cut out of circuit. By moving the switch-arm up to its contact-point *P* the magneto is cut out of circuit, and the primary battery alone furnishes current. When the battery is used, the current passes through the reactance coil, but not when the magneto is furnishing the current. This system can be used in the same manner as that of Fig. 127, and is subject to the same restrictions regarding two or more igniters being in the closed position at the same time.

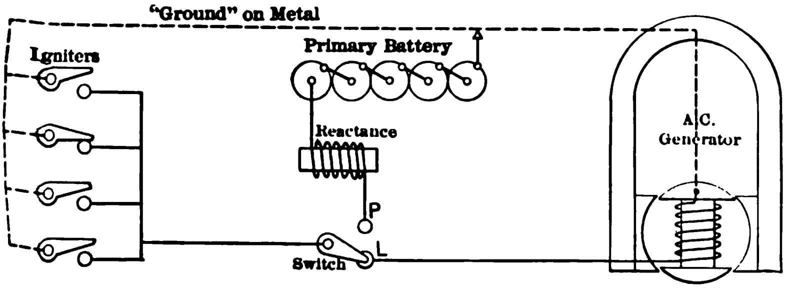


FIG. 128.

Four-igniter Low-tension Ignition System with Primary Battery and Alternating-current Magneto.

118. A storage battery " floated on the line " of a shunt-wound direct-current generator, and mechanical make-and-break igniters, are used in the system of Fig. 129. The current to the ig-

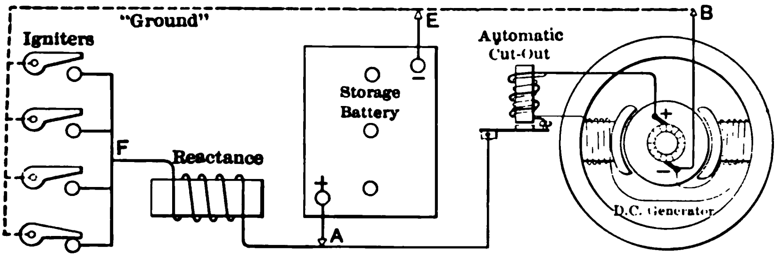


FIG. 129.

Ignition System with Four Low-tension Igniters and a Storage Battery Floated on the Line.

niters always passes through the reactance coil. The use of a storage battery in conjunction with a generator in this manner has been discussed in earlier paragraphs.

No switches for opening the circuit are shown, but if one is placed between *A* and the automatic cut-out, or between the negative brush and the " ground " connection at *B*, it will cut out the generator from the system but will not stop the current through the field-coils of the generator. A switch between the storage battery and either *A* or *E* will cut out the battery completely. One between *A* and *F* will cut off all the current from

the igniters. When this last switch is open and the other two closed, the generator will charge the battery if the pressure at the brushes of the generator is higher than that of the battery.

119. 110-volt Generator and 6-volt Primary Battery Mechanical Make-and-break System.* — Fig. 130 is a system in which a 110-volt direct-current generator is driven by the gas engine

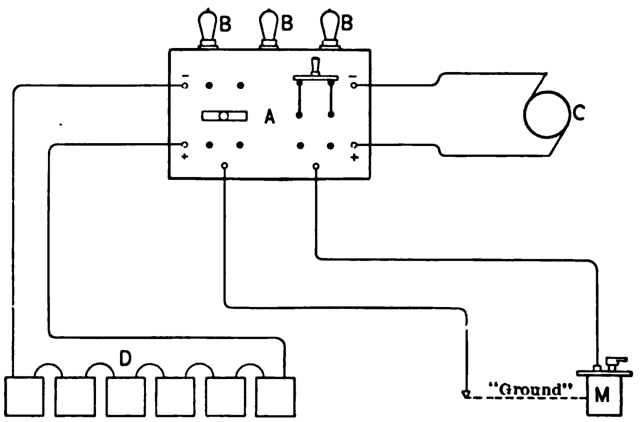


Fig. 130.
Make-and-break Ignition System Using a 6-volt Primary Battery and a 110-volt D. C. Generator.

to which it furnishes ignition current. A primary battery is provided for starting, since no current is available from the generator till it is well up to normal speed.

The chief items of the system, as furnished by the Westinghouse Machine Company, are:

A. Combination switchboard.

BBB. Three 110-volt 16-candle-power incandescent lamps with carbon filament.†

* The diagrams shown in Figs. 130, 133, 135, 136, 137, and 139 are slightly modified forms of those used by the Westinghouse Machine Company. They have been modified only enough to make them conform with the conventions used in this book. This modification does not change the ignition system.

† If incandescent lamps having filaments or "pencils" of other material than carbon are used, the lamps should be of a size requiring the same amount of current as the carbon-filament lamps specified. Any non-inductive resistance can be used in place of the lamps, the only requirement being that the amount of resistance shall be the same as that of the lamps specified.

C. 110-volt shunt-wound dynamo.

D. Edison primary battery, 6 cells.

The igniter *M* is part of the gas engine. Any number of igniters can be used, provided only one has its electrodes in contact with each other at any instant. In other words, not more than one igniter should be in the closed position at any instant.

The switchboard has two double-pole double-throw switches. The one at the right is called the dynamo switch. It is shown closed in its up-position with the handle at the top. The left-hand one is the battery switch. It is standing open in a horizontal position perpendicular to the vertical board. The handle appears as a circle.

Double-throw switches are used in order to reverse the direction of current through the electrodes of the igniter. The object in reversing the current is to secure equal rapidity of wear on the contact-points of the igniter. There is a tendency for one contact-point to wear more rapidly than its mate when the current always flows in the same direction through the igniter. The contact-point connected to the positive side of the circuit wears more rapidly, other conditions being equal for the two points.

When the switches are positioned as in Fig. 130, the battery is cut out of circuit and the generator is in circuit so that its positive brush is connected to ground.

The switchboard connections back of the board are shown in Fig. 131. The wiring is shown as if seen from the front through a transparent board. The reference letters are the same as in the preceding figure. A reactance coil is incorporated in the switchboard. The switch-blades of the dynamo switch are hinged to the middle terminals 1 and 2 of that switch.

When the dynamo switch is closed in the up-position as in Fig. 130, the current from the positive brush of the dynamo follows the path: Positive brush, 5, 4, through switch-blade to 2, ground, igniter *M*, reactance coil, lamps *BBB*, then through the connection to 1, switch-blade to 3, negative brush of dynamo. If the switch is thrown to its lower position with its handle down, the path of the current is then: Positive brush, 5, 1, lamps

BBB, reactance coil, insulated electrode of igniter *M*, ground, 2, 6, 3, negative brush of dynamo.

When the battery switch is closed and that for the dynamo open, the current does not flow through the lamps. If the battery switch is closed in its up-position, the path of the current

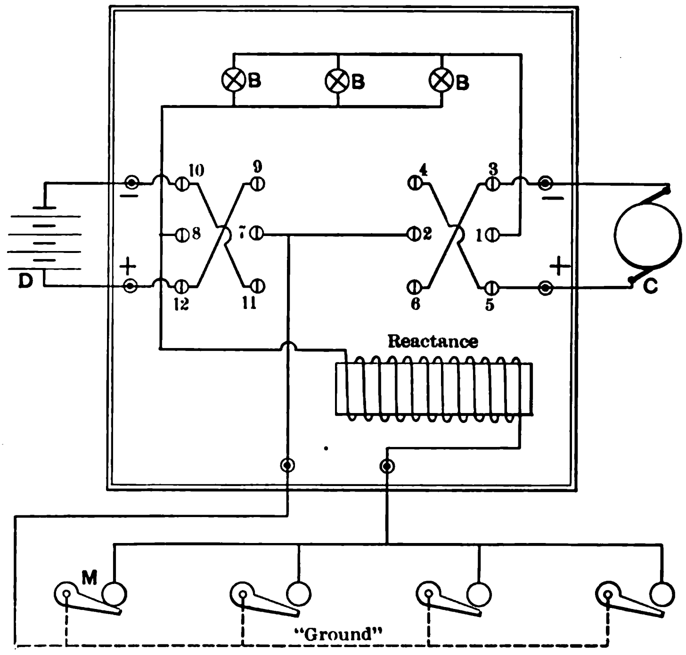


Fig. 131.
Switchboard Connections for Fig. 130.

is: Positive of battery, 12, 9, 7, ground, igniter *M*, reactance coil, 8, 10, negative of battery.

The amount of current that flows through the igniter when the dynamo alone is delivering current is regulated by the lamps. The three lamps specified, 110-volt, 16-candle-power, carbon-filament, will allow a current of 1.5 to 2 amperes to flow through the igniter, according to the efficiency of the lamps. This is three times the current that flows through one lamp, since they are in parallel with each other. The current flows through the

lamps only while one of the igniters is closed. The lamps flash once for each ignition when using dynamo current.

When the battery alone is in use, the lamps remain dark.

If both switches are closed, the generator will send current through the battery, at least during the time all of the igniters are open. Although this is not noticeably injurious if continued for only a short time, the primary battery will be injured if both switches are left closed during a long period of running.

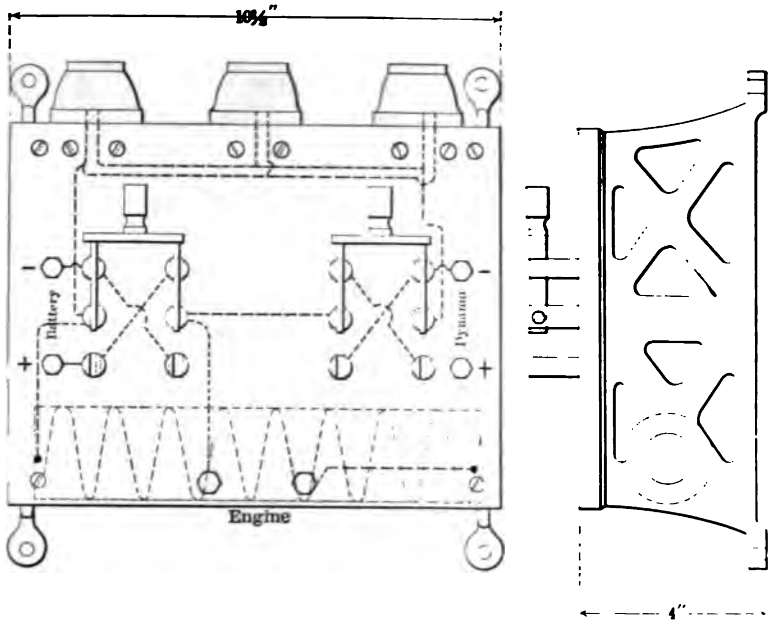


Fig. 132.
Switchboard Details for Fig. 130.

Fig. 132 shows front and side views of the switchboard as constructed. The lamps are not shown, but the lamp sockets appear.

120. Multiple System with Switchboards, Primary Batteries, and 110-volt Direct-current Generator. — The system in Fig. 133 is for two engines. Two switchboards of the kind just described are connected to one generator. Each switchboard has its

own primary battery. Fuse-blocks *E* are placed between each switchboard and the generator.

The system can be used either for two engines or for dual ignition in one engine. In the latter case, two igniters are placed in each combustion chamber. The two igniters in one com-

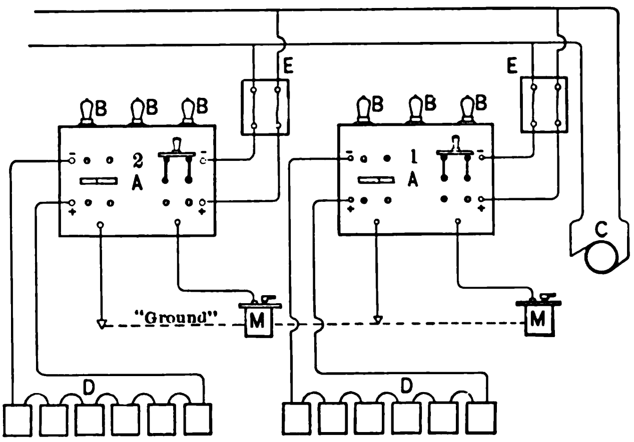


FIG. 133.

Two Switchboard Units for Distributing Current to Two Sets of Low-tension Igniters.

bustion chamber are closed and opened simultaneously, so that two ignition arcs are drawn in that combustion chamber at the same instant.

The system can be extended to any number of switchboards and the corresponding number of engines or of igniters in each combustion chamber of one engine.

The wiring diagram is shown in Fig. 134, in which each switchboard has four igniters. Two igniters, *M* and *M*, one connected to each switchboard, are shown closed, which is allowable in operation. Any igniter of one switchboard may be closed during the same time as any igniter of the other switchboard.

The dynamo switches must both be closed either in the up-position, as shown in Fig. 133, or both in the down-position, when the igniters connected to both boards are put into operation

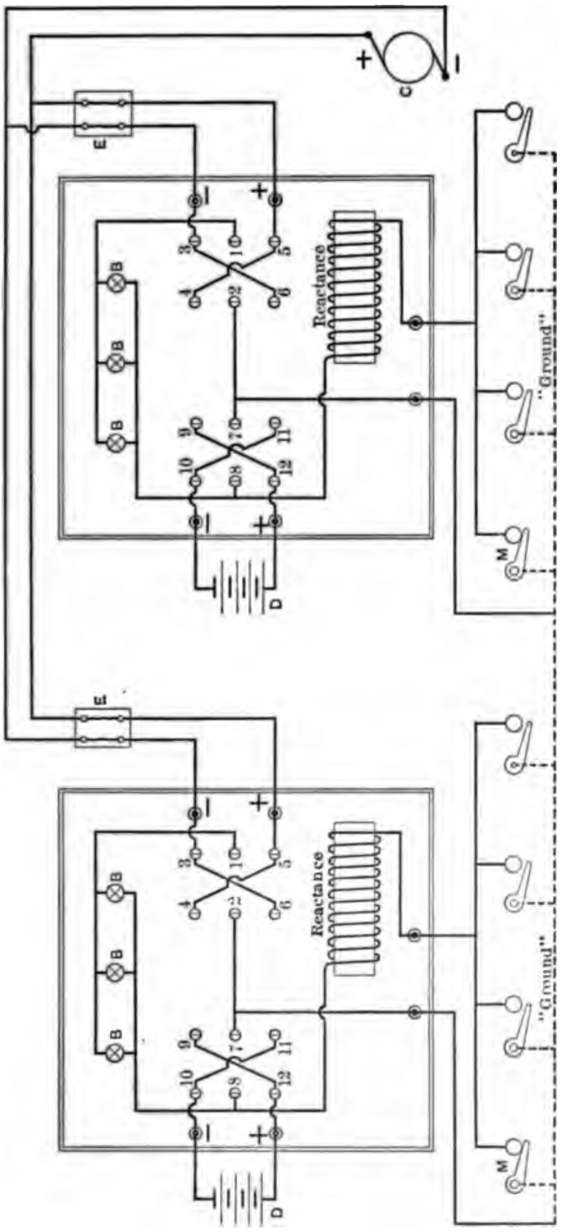


FIG. 134.
Connections for Fig. 133 when Four Make-and-break Igniters are Operated from Each Switchboard.

and while they are operating on current from the dynamo. If one dynamo switch is closed in the up-position, then closing the other dynamo switch in the down-position will short-circuit the dynamo, and one of the fuses at the fuse-blocks *E* will be melted or " blown," thus opening the dynamo circuit through one switchboard. The blowing of the fuse will stop ignition by the igniters connected to that board, unless the battery switch on the board is closed.

If the dynamo switch on board 1 is closed in the up-position, and the dynamo switch on board 2 is closed in the down-position, then the positive brush of the generator is connected direct to ground through board 1, and the negative brush of the generator is connected direct to ground through board 2, thus short-circuiting the generator as stated. A similar short circuit is made by reversing both of the dynamo switches from the positions just mentioned. The primary battery switch alone on one board can be left closed any length of time commensurate with the capacity of the battery, while either the dynamo switch or the battery switch is closed on the other board, or boards.

Reversing the dynamo switches during the operation of the system can be safely accomplished by first closing the battery switch on any one of the boards and then opening the dynamo switch on the same board. This should be done successively for all of the switchboards. The dynamo switches can then be closed in their reverse position, all of course being closed either up or down.

The battery switch on each board can be opened as soon as the dynamo switch on the same board is closed, or the battery switches can all be left closed till all of the dynamo switches are reversed, and then all of the battery switches can be opened.

Specifically, for two boards, the reversal of the dynamo switches can be done as follows, referring to Fig. 133, in which the battery switches are closed in the up-position and the battery switches are open: Close battery switch on board 1 in either the up- or down-position; open dynamo switch on board 1; close battery switch on board 2 in either the up- or down-position; reverse the dynamo switch on board 2 to the down-position;

open the battery switch on 2; close the dynamo switch on 1 in its down-position; open the battery switch on 1.

When there are more than two switchboards, the reversal of the dynamo switches can be carried out in a similar manner, leaving all of the dynamo switches open till that of the last board is reached, then reversing it and afterward closing the dynamo switches of the other boards and opening the battery switches.

121. Storage Battery and 110-volt Generator Mechanical Make-and-break System. — Referring again to the diagrams of Figs. 130 and 131 for one switchboard, a 6-volt storage battery may be substituted for the primary battery *D*. Then, if the dynamo switch and the battery switch are both closed in either the up-position or the down-position, the dynamo will send current through the storage battery to charge it during the time the igniters are all open. While an igniter is closed current will flow through it, and the breaking of the circuit by separating the contact-points of the igniter will draw an arc for ignition.

If the generator stops accidentally, as on account of the breakage of a belt for driving it, the storage battery furnishes current so that no interruption of ignition occurs. This when the switches are both closed before the accident. No automatic cut-out is necessary to protect the generator from excessive current sent through it when the generator stops. The lamps limit the current that the battery can send through the generator in such a case, and keep it small enough to prevent injury to the generator.

The path of the charging current, when the igniters are all open and the switches are both closed in the up-position, is (Fig. 131) from the positive brush of the generator to 5, 4, 2, 7, 9, 12, positive side of storage battery and through the battery, 10, 8, lamps *BBB*, 1, 3, negative brush of generator. The amount of this current is regulated by the resistance of the lamps, and therefore is not greater than is safe for the battery. While both switches are closed in the down-position, a similar battery-charging action occurs. But if one switch is closed in the up-position and the other closed in the down-position, then the generator sends current through the battery in the direction to

discharge it. The switches should not be left closed long in these opposite positions.

The amount and direction of current through the storage battery while an igniter is closed are both variable in such a system as usually made up. This refers to operation while the generator is running and both switches are closed in their proper positions. The inductive reaction of the reactance coil and the length of time the contact-points of the igniter are kept together both affect the action of the battery. The total result is that the storage battery is gradually charged during the operation of a properly designed system. The storage battery is thus kept ready to supply current for starting the engine and to keep it running for a considerable time.

The resistance (ohmic resistance) of the reactance coil is about one ohm, not including the inductive resistance.

The direction of current through the igniters can be reversed by reversing first one switch and then the other. The second switch should be reversed immediately after the first. Either switch can be reversed first.

122. Storage Battery, Primary Battery, and 110-volt Generator Make-and-break System. — Fig. 135 is a diagram of a system in which a storage battery is used in connection with a generator in the manner just described. A primary battery is also included in the system as a means of starting the engine when first installed and before the storage battery has been charged. The primary battery can also be used in an emergency.

The storage battery is shown at *F* and the primary battery at *D*. An additional switch *G* is provided for throwing either the storage battery or the primary battery into circuit. The switch is of the double-pole double-throw type. The switches are shown all three closed in the up-position so that the storage battery and generator are in operation. The primary battery is out of circuit.

To reverse the current through the igniters, the auxiliary switch *G* should first be thrown to the down-position so as to cut out the storage battery and put the primary battery into circuit. The two switches on the main board can then be re-

versed, one at a time. It is immaterial which of these two is reversed first. The auxiliary switch *G* is then to be thrown into its up-position again.

A 6-volt storage battery is suitable for use in this system. The switchboard is the same as that of Fig. 130.

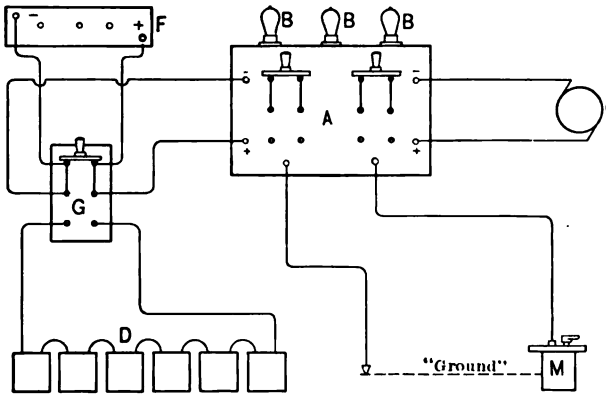


FIG. 135.
Low-tension Ignition System with Switchboard, Primary Battery, Secondary Battery and 110-volt D. C. Generator.

123. Multiple System with Storage Batteries, 110-volt Generator, Primary Battery, and Switchboards. — In Fig. 136 two units of switches and storage batteries, both the same as in the preceding figure, are connected to one generator and one primary battery. Fuse-blocks *E* are placed in the circuit in the same manner and for the same purpose as has been stated in connection with Fig. 133. Since the primary battery is intended only for starting the engine, or engines, one is all that is needed for both switchboards. The system can be extended to any number of switchboards.

The same precautions must be observed with regard to not having the dynamo switches closed in opposite positions as have been pointed out in connection with Fig. 133. The dynamo switches are those at the right-hand side of each of the switchboards 1 and 2. It is advisable to throw the auxiliary switches *G* up to the primary battery position before reversing the dynamo

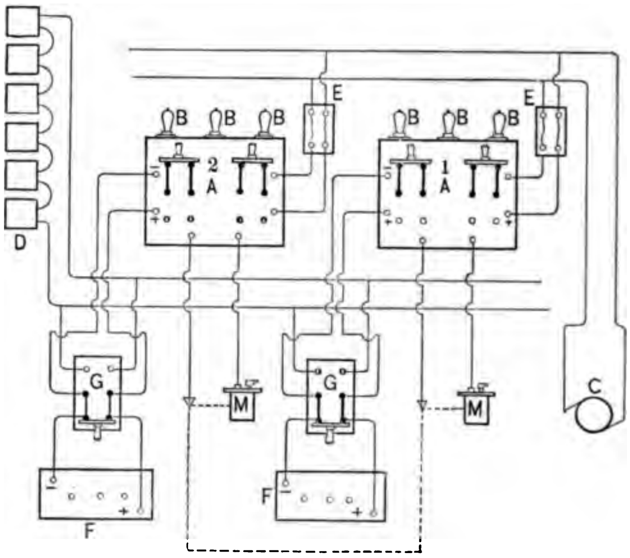


FIG. 136.

Two Switchboard Units, Two Storage Batteries, One Primary Battery, and One 110-volt D. C. Generator, for Supplying Current to Two Sets of Low-tension Igniters.

switches, and then throw them back to the storage-battery position after the reversal has been made.

124. System Using Current from 110-volt Direct-current Service without Ground Connection. — This system, Fig. 137, operates by charging one storage battery while another supplies current to the igniters. Neither side of the dynamo circuit is grounded at any time, therefore the switchboard can be connected to service wires such as supply 110-volt direct current for general use. *C* is the dynamo, and *M* one of the igniters on the engine.

The apparatus, as supplied by the engine builder, consists of:

A. Switchboard.

BBB. Three 110-volt 32-candle-power carbon-filament lamps.*

* If incandescent lamps having filaments or "pencils" of other material than carbon are used, the lamps should be of a size requiring the same amount of current as the carbon-filament lamps specified. Any non-inductive resistance can be used, the only requirement being that the amount of resistance shall be the same as that of the lamps specified.

FF. Two 6-volt storage batteries.
D. One 6-cell primary dry battery.
G. One double-pole double-throw 4-blade switch.
E. One 15-ampere fuse-block.

The connections in the switchboard *A*, Fig. 137, are shown in Fig. 138. The switch-blades are hinged at 1, 2, 3, and 4.

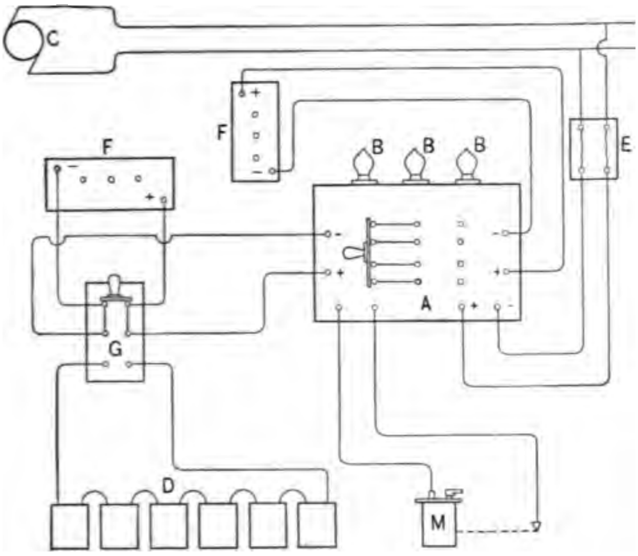


FIG. 137.

Switchboard and Low-tension Igniter Connections for Two Storage Batteries, One Primary Battery, One 110-volt Generator and One Set of Low-tension Igniters.

When the switches are closed in the positions shown in Fig. 137, the current to the igniters comes from the storage battery that is connected to the right-hand side of the switchboard. The path of this current is from the positive terminal of that storage battery to 11 (see Fig. 138), and flows on to 7, 3, ground, igniter *M*, reactance coil, 4, 8, 12, and the negative terminal of the battery. At the same time, the charging current for the other storage battery comes from the service to 13 and flows on to 2, 6, 9, auxiliary switch *G* (Fig. 137), positive terminal of battery

that is being charged, through the battery to its negative terminal, switch *G*, 10 (Fig. 138), 5, 1, lamps ***BBB***, and the terminal 14, to which the negative side of the service is connected. The charging current is regulated by the resistance of the lamps, which limit it to the amount that will pass through them.

When the 4-blade switch is thrown over to its right-hand closed position, the storage battery connected to the left-hand

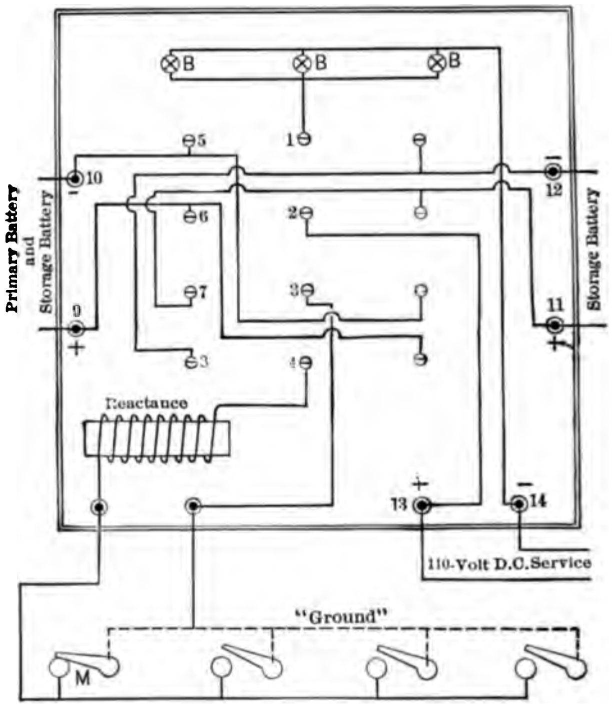


FIG. 138.
Switchboard Connections for Fig. 137.

side of the switchboard then furnishes current to the igniters, and the other storage battery receives charging current from the service. In this new position of the 4-blade switch, the current flows through the igniters in the opposite direction from that in which it did before.

The primary battery is for starting a new plant before either of the storage batteries is charged. It can of course be used temporarily in case of emergency.

While this system has been referred to as using 110 volts, it is satisfactorily operative at any voltage from 110 to 125.

125. Multiple System Using 110-volt to 125-volt Direct Current from General-service Circuit. — This system, Fig. 139, is a

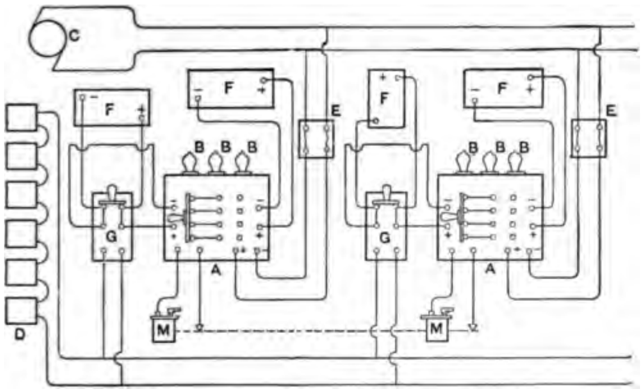


FIG. 139.

Two Switchboard Storage-battery and Igniter Units like Fig. 137, together with One Primary Battery and One 110-volt D. C. Generator.

multiplication of the switchboard, switch, and storage-battery units of the last-described system. Only one primary battery is used. It is connected to both switchboards.

No precaution to avoid short-circuits of the nature mentioned in connection with Fig. 133 is necessary in this system since each storage battery connected to the service for charging it has its own independent circuit that is without ground connection, and each battery delivering current to the igniters has a circuit through its own switchboard only.

126. A triple low-tension ignition system for a large engine with four double-acting cylinders is shown in Fig. 140. Each of the eight combustion chambers has three mechanically operated igniters. This is twenty-four igniters for one engine. The complete system for one engine is shown, together with the

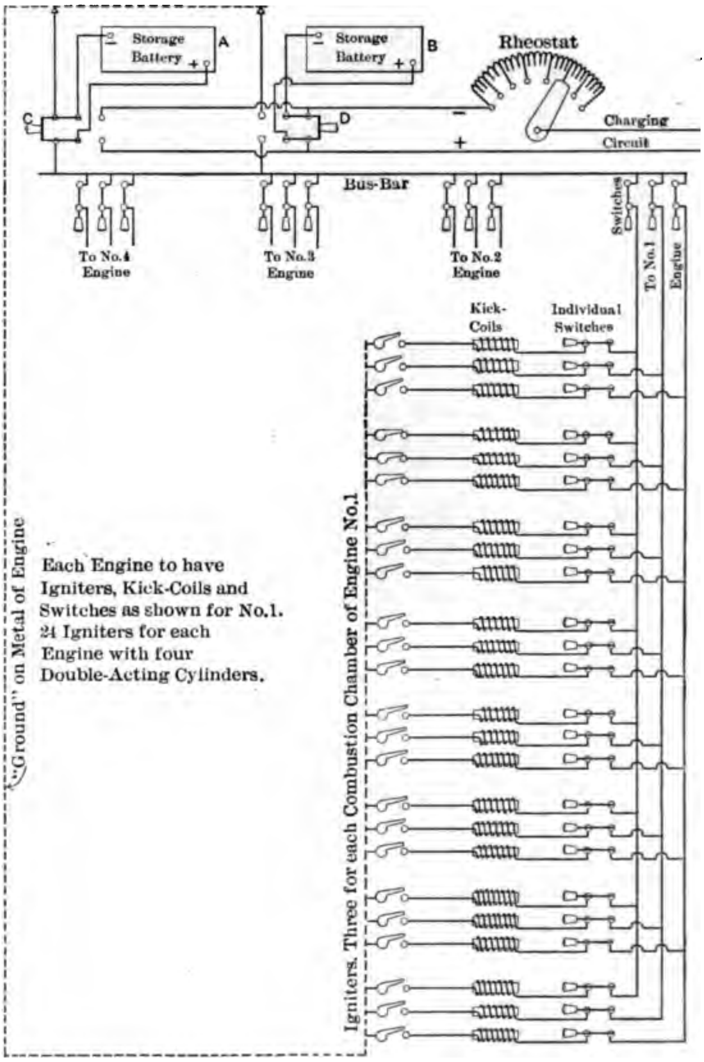


FIG. 140.

Connections for Low-tension Ignition System with Three Igniters in Each of Eight Combustion Chambers of One Engine, with Provision for Extending to Any Number of Engines. Two Storage Batteries Operating on Direct Current from a Generator.

bus-bar of a switchboard and the switches for circuits leading out to the igniters of three other engines. The system can be extended to any number of engines.

Electric current is furnished to the igniters by storage batteries only. As shown, battery *A* is connected through the switch *C* to the bus-bar on the positive (+) side, and to ground on the negative (−) side. The other battery, *B*, is connected by the switch *D* to both sides of a charging circuit through a rheostat for regulating the amount of charging current flowing through the battery. *C* and *D* are both double-pole double-throw switches. By reversing both of them, battery *B* will supply current to the igniters while battery *A* receives a charge from the service wires.

One side of each igniter is grounded to the metal of the engine. The negative (−) side of the battery which is supplying current to the igniters is also grounded during the time its switch is in the position for it to furnish current to the igniters. The "ground" is represented by the broken line in the figures.

The three igniters in one combustion chamber operate simultaneously. The second group of three igniters from the top are shown closed. These three igniters are all for one combustion chamber. They all three break contact at the same instant so as to form three ignition arcs simultaneously.

Each igniter is provided with its own individual switch, which when open cuts the igniter and its kick-coil out of circuit without interfering with the operation of any other part of the ignition system. One igniter in each combustion chamber is fed current through one of the three switches located at the bus-bar. The three switches for engine No. 1 are at the right-hand end of the bus-bar. The bottom igniter in each group of three is connected to the switch at the extreme right-hand end of the bus-bar. Opening this switch cuts out one igniter in each of the combustion chambers. The middle igniter in each group of three is similarly connected to the second switch from the right-hand end of the bus-bar; and the top igniter of each group is connected to the remaining switch for engine No. 1 at the bus-bar. Safety fuses should be put in at each switch.

The above ignition system is essentially that designed for twelve engines of 3200 horse power each. Tell-tale kick-coils of the nature of that shown in Fig. 123 are used, and the ignition apparatus at the engine is of the general nature of that in Figs. 114 and 115. Each storage battery has five cells so as to give an average of about 10 volts while discharging.

CHAPTER XIV.

ELECTROMAGNETIC IGNITERS AND IGNITION SYSTEMS FOR LOW-TENSION CURRENT.

127. Principle of Operation. — In an electromagnetically operated igniter of the simplest form, the contact-points at which the arc is drawn for ignition are generally kept pressed together by a spring without current flowing through them until the instant at which ignition is to occur. An electromagnet forms part of the igniter. As soon as the electric circuit is closed, as by a timer which is a mechanically driven piece of apparatus separate from the igniter, current begins to flow through the magnet-coil and the contact-points of the igniter, and continues until the contact-points are separated by the action of the electromagnet. The latter is energized by the current flowing through it. The separation of the contact-points first draws an arc suitable for ignition, and then breaks down the arc, thus stopping the flow of current. The electromagnet also acts as a kick-coil to produce a suitably hot arc. The electromagnet then loses its magnetism and the contact-points of the igniter are drawn together again by the action of the spring already mentioned. The different pieces of apparatus are generally, and preferably, so adjusted that the circuit is broken at the timer after the arc is broken down at the ignition-points, and before the contact-points of the igniter come together again after the arc is broken down.

128. Elementary Ignition System with a Timer and an Igniter having an Electromagnet with a Plunger Core. — In Fig. 141, *A* is the stationary contact-ring, and *B* the movable contact-point, between which the ignition arc is drawn inside of the combustion chamber of the engine. The stationary contact-ring *A* is rigidly attached to the rod *C* which extends outside of the engine cylinder. *C* and *A* are both insulated from the metal of

the engine. The movable contact-point *B* is carried by the rocker-arm *D*, which is fastened rigidly to the rod *E* that extends outside of the engine cylinder and has an arm *F* rigidly attached to its outer end. The tension spring *G* pulls on the arm *F* so as to press the movable contact-point against the stationary con-

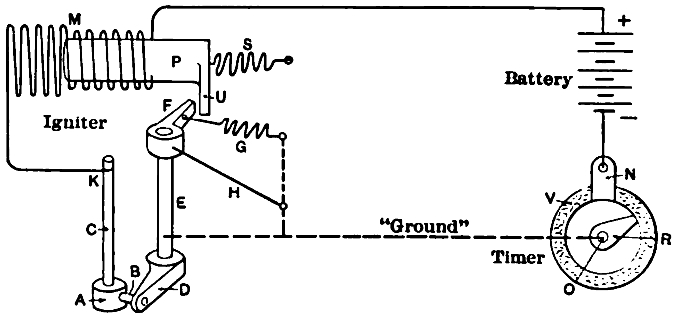


FIG. 141.

Elementary Low-tension Ignition System with Electrically Operated Igniter.

tact-ring. One end of the spring is fastened to some stationary part of the igniter. As represented in the illustration, the movable rod *E* makes metallic (electric) contact with the metal of the engine, and the arm *F* is electrically connected to the engine metal by the spring *G*. In addition to this, a copper wire *H* connects *F* to the metal of the engine, the only purpose of this wire being to insure a perfect " ground " connection for the movable electrode.

The electromagnet which forms part of the igniter is represented by the solenoid coil *M* and the plunger-core *P*. The core is shown held partly out of the coil by the tension spring *S*, whose right-hand end is fastened to some stationary part of the igniter. One end of the magnet coil *M* is connected at *K* to the outside end of the stationary insulated electrode; the other end of the wire of the magnet winding is connected to one side of the battery. The other side of the battery is connected to the metallic contact-piece *N* of the timer for closing the electric circuit when ignition is to occur. The contact-piece *N* is fastened to a cylindrical piece of insulating material *V* which forms the body of the timer. A metal arm *R* is connected to a shaft

O which rotates in a bearing at the center of the body of the timer. *R* and *O*, which together form the rotor of the timer, are electrically connected to "ground." The broken line indicates ground connection.

As the rotor *R* revolves, its outer end makes electric contact with the stationary contact-piece *N*, thus closing the electric circuit through the igniter once every revolution of the timer. Electric current begins to flow through the igniter as soon as the timer closes the electric circuit. The path of the current, starting from the positive (+) side of the battery, is through the coil *M* to the terminal *K* of the insulated electrode of the igniter, thence through the contact-pieces *A* and *B* of the igniter, and through "ground" to the rotor *R* of the timer; from *R* the current goes to *N*, when the latter two parts are in contact with each other, and thence to the negative (−) side of the battery.

As soon as the current obtains sufficient strength, the consequent energizing of the magnet-coil draws the plunger *P* farther into the coil and causes the tappet *U* to strike the end of the arm *F* so as to rotate the movable electrode slightly and thus move the contact-point *B* away from *A*. This breaks the circuit inside the combustion chamber and draws an electric arc for ignition. The breaking down of the arc, which occurs immediately after it is drawn, interrupts the current. The magnet coil then becomes de-energized, and the spring *S* draws the plunger *P* back again to the position shown. The spring *G* at the same time pulls the contact-point *B* against the contact-ring *A* inside the combustion chamber again. In the meantime the rotor *R* of the timer should have moved out of contact with *N*. If *R* has not moved out of contact with *N* by the time the ignition-points *A* and *B* are together again after drawing an arc, then the action of the igniter will be immediately repeated, which is undesirable.

129. Dual Ignition System with Plunger-core Electromagnets in the Igniter. — Fig. 142. The igniters used in this system are of the plunger-core magnet type and operate in the same general manner as the one shown in the preceding figure. Each igniter has two electromagnets; also two pairs of contact-points inside

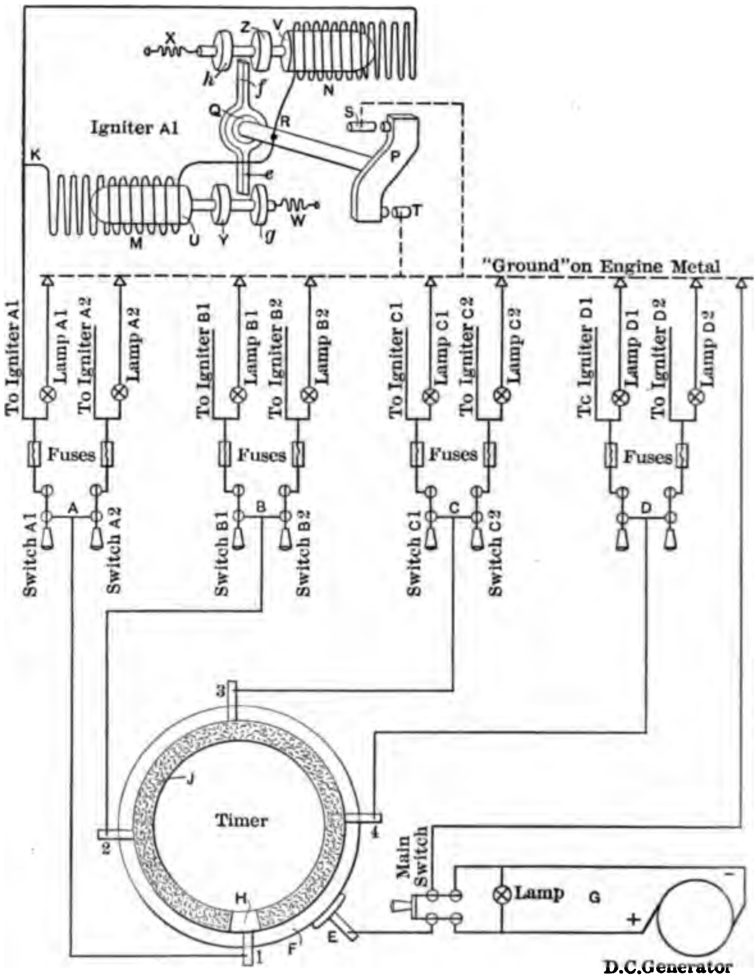


FIG. 142.

Connections for Low-tension Ignition System with Two Electromagnetic Igniters for Each of Four Combustion Chambers of One Engine. The Details of the Igniter and Timer are shown in Figs. 143 and 144.

of the combustion chamber. Two igniters are used in each combustion chamber; eight igniters for the four combustion chambers. Only one igniter is shown. This system has been operated on 110-volt current from a direct-current generator.

The timer shown has four brushes, 1, 2, 3, and 4, which bear against a ring containing a long segment *J* of insulating material (vulcanized fiber) and a short segment *H* of metal. The short segment *H* is electrically connected to a complete metal ring *F* against which a brush *E* bears. Current from the source of supply is received at the brush *E*. As the rings of the timer rotate, the short metal segment *H* successively makes contact with the four brushes which bear against the ring *J-H*, thus causing current to be delivered successively to these four brushes.

When the timer is in the position shown, current flows from the positive (+) brush of the generator through the lower blade of the double-pole main switch to the brush *E*, slip-ring *F*, segment *H*, brush 1, and thence to *A*, where the current divides, part going to switch *A* 1 and part to switch *A* 2. These two switches are for the two igniters which are in one combustion chamber and operate simultaneously.

The current from switch *A* 1 passes through a safety fuse and then divides, part going to ground through tell-tale lamp *A* 1 and the remainder to igniter *A* 1. The current to igniter *A* 1 divides at *K*, part going through magnet-coil *M* to the insulated rod *R*; the other portion flows through magnet-coil *N* to *R*. The current flows through the rod *R* to the movable contact-points carried by the rocker-arm *P* attached to *R*, and thence to the stationary contact-points *S* and *T*, both of which are grounded on the metal of the engine. The current from ground flows through the upper blade of the main switch to the negative (−) brush of the generator.

Before current begins to flow through the igniter, the movable contacts in the arm *P* are pressed against the stationary contacts by action of the tension springs *W* and *X*. These springs pull the plungers *U* and *V* partly out of the coils until the movement of the plungers is stopped by the rings *Y* and *Z* striking against the arms *e* and *f* and moving them back till the movable contacts

are pressed against the stationary ones in the combustion chamber. As soon as the current flowing through the magnet coils attains sufficient volume, after the closing of the circuit by the timer, the plungers are magnetically drawn into the coils, thus causing the rings *g* and *h* to strike the arms *e* and *f* and separate the ignition contact-points in the combustion chamber. The plungers move some distance into the coils and gain considerable speed before the rings *g* and *h* strike the arms, thus causing rapid separation of the ignition-points. The space between the rings *Y* and *g* is greater than the thickness of the arm *e*, and the construction of the upper rings and arms is similar, in order to obtain this hammer-blow action to separate the ignition contact points. The double-arm member *e-f* is insulated from the electrode rod *R* by the insulating ring, or bushing, *Q*.

The current from switch *A* 2 passes through a safety fuse and then divides, part going to ground through tell-tale lamp *A* 2 and the remainder to igniter *A* 2 (not shown). Igniter *A* 2 is in the same combustion chamber as igniter *A* 1. Both of these igniters operate at the same instant, thus drawing two arcs, one at each igniter, to ignite the combustible charge in one cylinder.

The lamps *A* 1 and *A* 2 both flash each time the timer closes the circuit at the brush 1 as shown, during the rotation of the rotor of the timer, provided the switches *A* 1 and *A* 2 are both closed and the system is operating properly. If one of the fuses blows, the corresponding lamp remains dark. Each of these lamps indicates whether current is going properly to the corresponding igniter. The movement of the igniter indicates whether it is operating as it should.

Each pair of igniters is connected into the system in the same manner as just described for igniters *A* 1 and *A* 2. This is indicated by the lettering on the diagram.

The lamp *G* is for indicating whether there is current in the main circuit from the generator. This lamp glows continuously while the pressure in the main circuit is correct.

Only one ignition arc is drawn when the two pairs of contact-points of one igniter are separated. This arc sometimes occurs at one pair of ignition-points, and sometimes at the other pair.

The life of the contact-points is, therefore, practically doubled by the use of two pairs of ignition-points, as compared with only one pair for the same igniter.

The igniter and timer whose elements are shown in the accompanying illustrations are shown in detail in the following two sections.

130. Wisconsin Engine Company's Electromagnetic Igniter with Plunger Cores. — Fig. 143, five views, (*A*), (*B*), (*C*), (*D*), and (*E*). This igniter has two pairs of contact-points, of which both movable points, 1 and 2, are attached to the same double-ended rocker-arm 3. The stationary contact-points, 4 and 5, are inserted in lugs 6, 6, which project from the inside end of the body of the igniter, and are part of the body casting. The body of the igniter fits into a cylindrical hole which pierces the cylinder wall of the engine; the body makes a tight joint near its inside end. The material of the engine cylinder is represented by the short herring-bone lines. The body of the igniter is in metallic (electric) contact with the metal of the engine cylinder.

The rocker-arm 3 is carried on the live spindle 7 which passes through the insulated metallic tube 8 from end to end of the igniter body; the tube forms a bearing for the spindle. The tube 8 is insulated from the body of the igniter at the inner end by means of the mica washers 9, and at the outer end by a wood-fiber bushing 10. A nut 11 fits on the outer end of the tube 8 to hold the tube in place. A coiled compression spring 12 and a pair of metallic washers 13 are placed between the nut 11 and the insulating bushing 10. The expansive force of the coiled spring acts to keep the flange of the inner end of the tube 8 tightly pressed against the mica insulating washers 9 so as to maintain a tight joint unaffected by different amounts of expansion in contiguous parts on account of the heat of combustion.

Two arms, 14 and 15, are rigidly attached to the outside end of the spindle 7 for rocking the contact-points. These arms are insulated from the spindle by the flanged bushing 16. The two cap-screws, one on each side of the spindle, are tightened to grip the arms on the spindle 7.

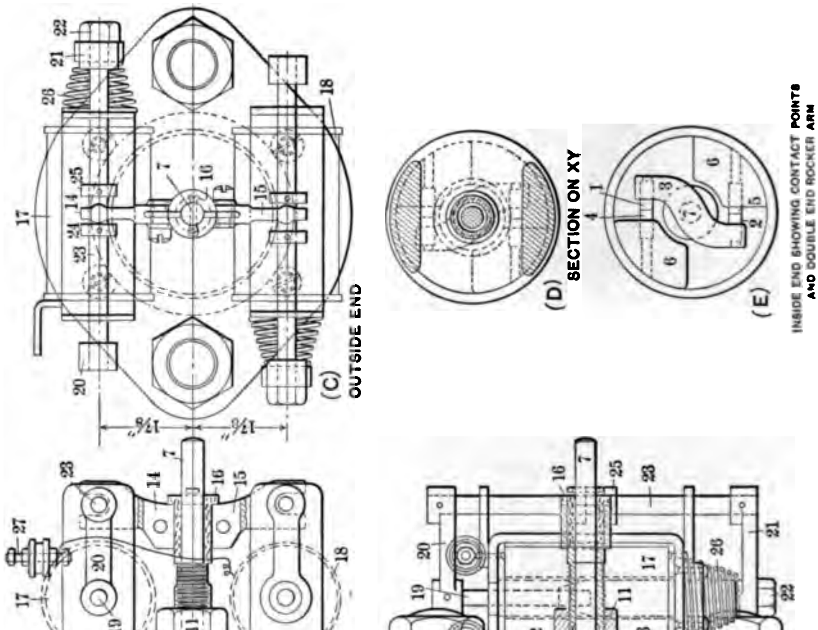


FIG. 143. (*See also* Fig. 142.)
Electromagnetic Igniter with Two Pairs of Ignition Points and Plunger-core Magnets. Wisconsin Engine Company, Corliss, Wisconsin.

Two solenoid coils, 17 and 18, each with a soft-iron or mild-steel plunger-core, are used for separating the contact-points at which the arc is formed for ignition. The plunger-core of coil 17 is shown by dotted lines in view (*B*); the end inside of the coil is tapered and bored to receive one end of a non-magnetic rod 19, whose opposite end is fastened to a bar 20 that forms part of a yoke. The end of the steel plunger-core that extends beyond the end of the solenoid 17 is fastened to the yoke-bar 21 by means of the nut 22. The end bars, 20 and 21, of the yoke are also connected together outside of the solenoid by the rod 23, which engages with the forked end of the arm 14 that is fastened to the insulated spindle 7 of the rocker-arm, as already described. A coiled compression spring 26 is placed between the yoke end-bar 21 and the end of the solenoid coil 17. The expansive force of this spring keeps the collar 24 pressed against the arm 14 when no current is flowing through the solenoid. The parts 19 to 26 are duplicated in connection with the solenoid 18. The action of the two springs 26 is to keep the ignition contact-points pressed together.

When the ignition timer (not shown) closes the electric circuit so that current flows through the two magnet coils in parallel, the steel plunger-core of each solenoid is drawn farther into the coil than when no current is flowing. This drawing in of the plunger brings the collar 25 against the side of the arm 14, and likewise the duplicate of collar 25 against the side of arm 15. This moves the arms 14 and 15 so as to rock the rocker-arm 3 and thus separate both pairs of contact-points, 1-4 and 2-5. The plunger-cores move rapidly and gain considerable speed before the collars 25 strike the arms 14 and 15. Consequently the collars strike a hammer-blow against the arms so as to cause rapid separation of the contact-points at which the ignition arc is to be formed.

The terminal (binding post) to which the wire from the source of electricity is connected is shown at 27. The current divides at this terminal and flows through the two magnet-coils in parallel and thence to the metallic washers 13 on the insulated electrode rod 7.

The ignition contact-points, 1, 2, 4, and 5, can be driven out for renewals by using a punch or piece of small rod inserted in the slightly reduced extension of the hole into which each point is fitted. The makers of this igniter find that the use of two pairs of contact-points doubles the life of the points as compared with an igniter using only one pair of contact-points.

The igniter is constructed for use on 110-volt circuits. The thickness and number of turns of wire in each magnet-coil of course determine the voltage that is suitable.

131. One-ring Timer for Large Engine with Four Combustion Chambers. — The complete constructional form of a timer for use with electromagnetic igniters is shown in Fig. 144. The end view is shown at (*A*), the side view at (*B*), and one of the brush-holders at (*C*). The mechanism for varying the time of ignition is shown in Fig. 145 in connection with the ring, or spider, which carries the brush-holders. This timer embodies the slip-ring and segmental ring shown in elementary form in Fig. 142.

In Fig. 144 the current is brought to the timer by the wire 1 connected to the brush 2 which bears on the slip-ring 3. Part of the slip-ring 3 is broken away at the top in view (*A*) in order to expose the upper part of the long segment 4 of insulating material and the side of the short metallic segment 5, which together form the ring on which the four brushes 6, 7, 8, and 9 bear. The slip-ring 3 and the composite ring 4-5 are carried by the heavy metal ring 10 which fits on the shaft 11. The slip-ring 3 is broken away under the brush 2 in view (*A*) so that the brush apparently bears on the heavy ring 10, but this is not actually so, since the brush is farther forward than the ring. The segment 5 is metallically connected to the slip-ring 3, but is electrically insulated from all of the other parts of the rotor.

The brush 6, of the four similar brushes, fits into the brush-holder 12, which is hinged to the bracket 13. This bracket is fastened to a piece of insulating fiber 14. A coiled compression spring between the fiber and the brush end of the holder presses the brush against the rotor of the timer. The fiber 14 is fastened to a metal segment 15, which is flanged to fit into a circular

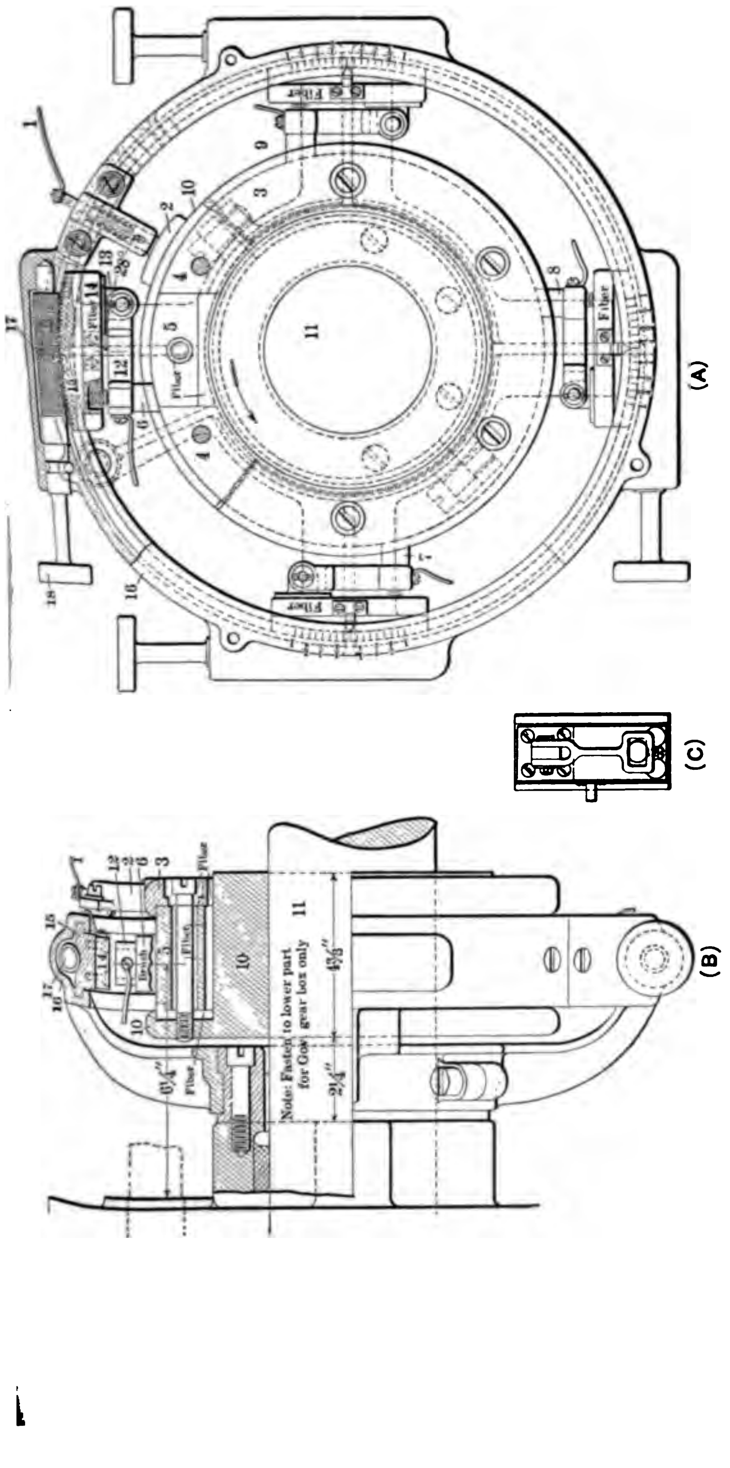


FIG. 144. (*See also* Figs. 142 and 145.)
Timer, or Low-tension Distributer, for Four Pairs of Electromagnetic Igniters. Wisconsin Engine Company.

groove in the ring 16. The ring 16 carries all of the brush-holders and is integral with four arms and a hub mounted coaxial with the rotor of the timer. The segment 15 has worm-wheel teeth into which the worm 17 meshes. This worm can be rotated by means of the hand-wheel 18 on an extension of the worm. By

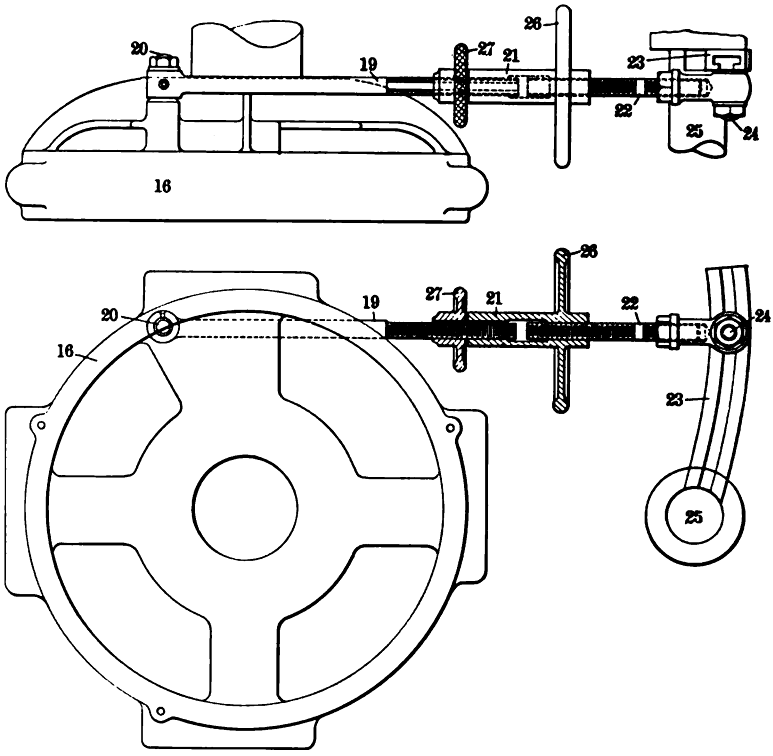


FIG. 145.
Ignition Advance-and-retard Mechanism for the Timer shown in Fig. 144.

rotating the hand-wheel, the brush is moved circumferentially around in the supporting ring so as to vary the time of ignition at the igniter, or igniters, connected to this brush. The wire leading from the brush-holder to the timer, or timers, in one combustion chamber is connected to the brush-holder by means of the small screw at the left-hand end of the holder. Each of the brushes, 7, 8, and 9 has its own brush-holder, which is carried

by the ring 16 in the manner just described for brush 6, and is individually adjustable in the same manner for varying the time of ignition of its igniter, or its igniters.

In addition to the individual adjustment of the brushes as just described, all of the brushes can be rocked collectively around the rotor of the timer in order to simultaneously vary the time of ignition in all of the combustion chambers of the engine. The means for doing this are shown in Fig. 145. In this figure, the left-hand end of rod 19 is hinged to the brush-carrying ring 16 by the bolt 20. The right-hand end of the rod 19 is threaded into the corresponding end of a sleeve 21. Another rod, 22, is threaded into the right-hand end of sleeve 21, and the right-hand end of this rod is hinged, by means of an end-piece, to the rocker-arm 23 by the T-head bolt 24, whose head fits into a slot in the rocker-arm. The rocker-arm is fastened to the shaft 25, which is connected to the governor of the engine. The governor rocks the shaft 25 as the speed of the engine varies, and thus rocks the brush-carrying ring 16 so as to advance or retard the time of ignition in each combustion chamber by the same amount. The extent of the rocking motion given to the brush-carrying ring can be decreased by moving the bolt 24 down nearer to the shaft 25, or increased by moving this bolt farther away from the shaft 25.

Hand adjustment of the time of ignition is obtained in all of the combustion chambers simultaneously by turning the threaded sleeve 21 on the bolts 19 and 22. The sleeve has a right-hand thread at one end and a left-hand thread at the other. A hand-wheel 26 is provided for rotating this sleeve-nut. A lock-nut 27 prevents the sleeve-nut from rotating after the desired setting is obtained.

132. Allis-Chalmers Four-ring Timer for Large Engine. — In the photograph, Fig. 146, the ring N near the front end of the timer rotor, and the ring P at the back part, are both complete metallic slip-rings. The segment E is electrically connected to the adjacent front slip-ring N, and these two parts are insulated from all of the other parts of the rotor. The segment E forms part of a four-segment ring of which the other three metallic

segments are two short segments, one at each end of *E*, and a long segment, one end of which is visible at *K*. The long segment *K* and the two short segments are insulated from each other and from all other parts of the rotor. The segment *F* in the third ring from the front end of the rotor is electrically connected to the adjacent slip-ring *P*. Segment *F* is like segment

FIG. 146. (*See also* Figs. 147, 148, 149, and 150.)
Four-ring Timers, Switches, and Lamps for Four Pairs of Electromagnetic Igniters. Allis-Chalmers Company, Milwaukee, Wisconsin.

E, and is part of a four-piece ring like that of which *E* is a segment. *F* and *P* are together insulated from the remainder of the rotor. In the ring of which *E* is a part, the other three metallic segments are electrically insulated from each other and from all other parts of the rotor. None of the parts which have been mentioned has electric connection with the metal of the engine. The timer is therefore without "ground" connection.*

* In the diagram, Fig. 150, the rings of the timer are shown separated from each other, side by side, together with the brushes bearing on them. The reference letter is the same for any one part in both the photograph and the diagram, when the letter appears in both.

The assumption of which is the positive, and which the negative side of the supply circuit, as made below, is merely for convenience of description.

The negative side of the main switch is connected to the brushes *J* and *Y* (shown at about the same level on opposite sides of the timer), both of which bear on the slip-ring *N*. Segment *E* is therefore negatively electrified, since it is electrically connected to slip-ring *N*.

The positive side of the main switch is connected to the brushes *I* and *L* (one at the top and the other at the bottom of the timer), both of which bear on the slip-ring *P*. Segment *F* is connected to slip-ring *P*, and is therefore positively electrified.

Brush *G* bears on segment *E*, and brush *H* (next below *G*) bears on segment *F*. These brushes are connected to the two double-pole switches *A*1 and *A*2 on the switchbox above the timer. Each of these two brushes is connected to one blade of each of these two switches. Switch *A*1 is connected to one igniter, and switch *A*2 to the other, of two igniters in the same combustion chamber of the engine. These igniters operate simultaneously.

Four brushes bear on the ring of which *E* is a segment. The three of these brushes other than *G*, all bear on the long segment *K* when the rotor is in the position shown. Segment *K* is always electrically dead. The ring of which *F* is a segment also has four brushes bearing on it, three of which are on the long, dead segment as the rotor is shown. The pair of brushes, *G* and *H*, are the only ones, of those on the segmental rings, that are electrified while the rotor is in the position illustrated.

As the rotor revolves, the electrified segments *E* and *F* first pass completely out of contact with the brushes *G* and *H*, then make contact with the next similar pair of brushes, thus directing the current to another pair of igniters in another combustion chamber. The electrified segments *E* and *F* pass successively under all four of the brushes that bear on the segmental rings, thus successively directing current to the four pairs of igniters in the four combustion chambers. There are four more switches on the back part of the switchbox, which are not visible in the illustration. Two safety fuses are located under each switch.

The two short segments, one at each end of the electrified segment *E*, are to prevent the long segment *K* from becoming momentarily electrified each time the segment *E* passes either out of or into contact with a brush. While the segment *E* is passing from under brush *G*, the brush momentarily bridges the insulation between *G* and the short segment. The latter is, therefore, momentarily electrified, since the brush is in contact with both the electrified segment *E* and the short segment. The latter is long enough to allow *E* to pass completely out from under the brush before segment *K* comes into contact with the brush. The brush is thus left dead before segment *K* comes into contact with it. The action is of the same general nature while segment is moving into contact with a brush.

Each of the white lamps on the top of the switchbox is connected to one circuit leading from the switch to an igniter. The lamp is connected across the circuit so as to be in parallel with the corresponding igniter. The lamp flashes each time the circuit to the corresponding igniter is electrified. The red lamp, in the midst of the white ones, is connected to the wires between the main switch and the slip-ring brushes of the timer. The red lamp glows continuously while the wires going to the slip-ring brushes of the timer are properly electrified; it remains dark while the main switch is open.

133. Allis-Chalmers Electromagnetic Igniter for a Large Engine. — The photographs, Figs. 147 and 148, are from slightly different viewpoints. The two views are shown in order to present the constructive form as plainly as possible. Several parts, which are completely hidden in the photographs, are shown in the detail drawing, Fig. 149. The essential elements of the igniter are shown in the skeleton drawing which is part of the wiring diagram, Fig. 150.

The reference number is the same for any one part in each of these figures where the part appears. All of the parts do not appear in all of the figures.

The plug 1 has a flange at its outer end, by means of which it is fastened to the engine cylinder. The casing 2 incloses the electromagnets and the magnet-armature which actuate the

FIGS. 147, 148, 149, and 150.

1. Igniter plug, flanged.
2. Housing, or casing, inclosing electromagnets and magnet-armature.
3. Shoulder which makes tight fit (with gasket) in wall of engine cylinder.
4. Contact-piece at ignition point of stationary electrode (insulated).
5. Rod of stationary electrode (insulated).
6. Arm carrying contact-point of movable electrode (insulated).
7. Outside end of insulated rod of movable electrode.
8. Arms rigidly fastened to outside end of insulated rod 7 of movable electrode.
9. Coiled tension spring for pressing the outer end of contact-arm 6 against the stationary contact-piece 4.
10. Hammer rigidly mounted on rocker-spindle 11, whose upper end extends through the top of housing 2.
11. Rocker-spindle on which hammer 10 and magnet-armature 23 (the latter not shown in Figs. 147 and 148) are rigidly mounted.
12. Fiber (insulating) button at the end of hammer-arm 10. This button strikes the arm 8 to separate the contact-points in the combustion chamber.
13. Adjusting screw with fiber button on the end. For preventing hammer 10 from rotating back too far after current stops in the igniter.
14. Tubular bushing (insulated) around the rocker-arm 7.
15. Mica washers, or rings, for insulating stationary electrode 4–5.
16. Mica washers, or rings, for insulating tubular bushing 14 together with movable electrode 6–7.
17. Collar clamped on rod 7 of movable electrode. A short coiled compression spring between this collar and the adjacent end of the tubular bushing 14 holds the hub of the arm 6 against its seat on the inside end of 14 so as to maintain a tight joint.
18. Bolts for fastening magnet-coils in place in housing 2.

The following parts are not visible in the photographic views.

19, 20. Coil winding of field-magnets.

21, 22. Cores and pole-pieces of the magnetic field.

23. Magnet-armature. Rigidly attached to rocker-spindle 11.

igniter. This casing is bolted to the flange of the plug proper. The shoulder 3, near the inside end of the plug, makes a gas-tight joint, with the aid of a gasket, in the wall of the engine cylinder.

The stationary contact-piece 4 at the point of ignition is

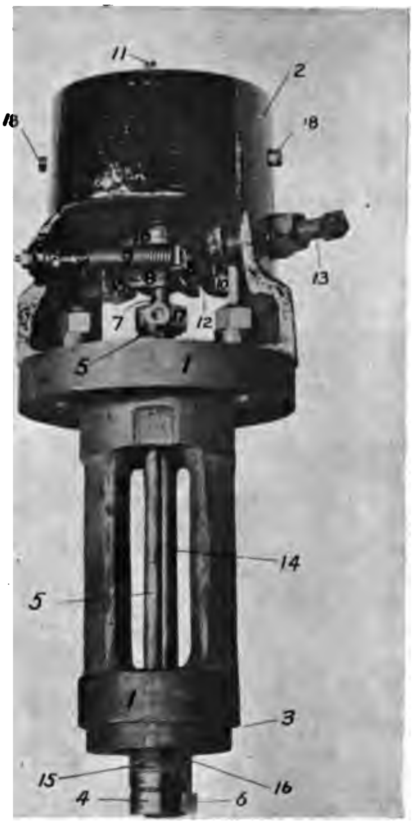


FIG. 147. (*See also* Figs. 148, 149, and 150.)
Electromagnetic Low-tension Igniter with Rocking Magnet-Armature.
Allis-Chalmers Company.

fastened to, or integral with, the rod 5, which together form the insulated stationary electrode 4-5. The outside end of the rod 5 projects slightly beyond the nut which holds the terminal of the wire through which current is brought to the stationary electrode. The rocker-arm 6 which carries the movable contact-ignition

point is fastened to a rod 7 which extends to the outside through an insulated tubular bushing 14. Only a portion of the outer end of 7 is visible in the photographs. To the outside end of 7 is clamped a two-armed piece 8, to the front arm of which is

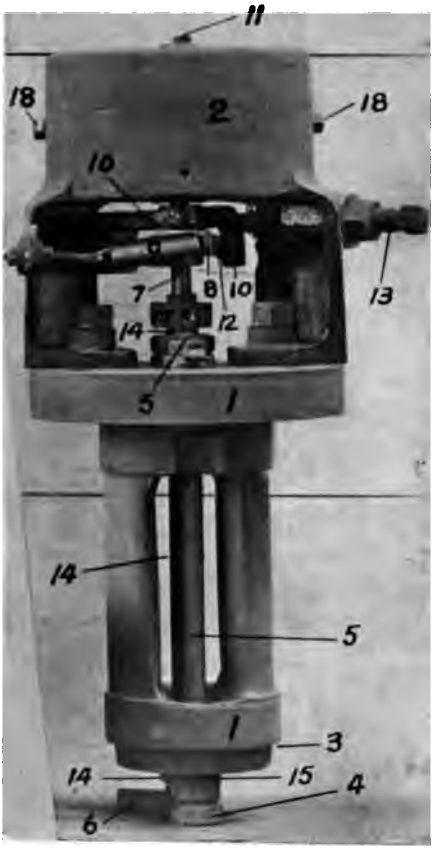


FIG. 148.
Another view of Fig. 147.

attached a coiled tension spring 9 for keeping the ignition-contact points pressed together when no current is flowing through the igniter. The rear arm serves as an anvil against which hammer 10 strikes so as to slightly rotate the electrode 6-7, thus causing separation of the contact-ignition points. The hammer 10 is

carried on a spindle which extends up through the housing 2. A fiber button 12 on the hammer 10 strikes the arm 8. This button prevents electric connection between 8 and 10. The eye-bolt at the left-hand end of the coiled spring 9 is insulated from the metal through which it passes. The two electrodes are completely insulated from the main body of the igniter. The adjusting screw 13 prevents the hammer 10 from swinging back too far. This screw has a fiber end against which 10 strikes. The mica washers 15 are for insulating the inner end of the stationary electrode; and the mica washers 16 are for insulating

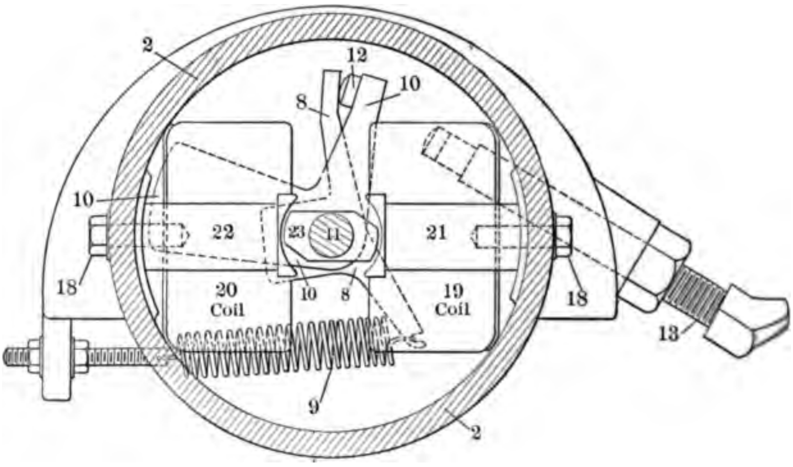


FIG. 149. (*See also* Figs. 147, 148, and 150.)
Detail of Electromagnets and Hammer of Igniter with Rocking Magnet-Armature.

the inner end of the tubular bushing 14. The collar 17 is clamped on the movable electrode rod 7, and has a coiled compression spring between it and the end of 14 for keeping the hub of the igniter arm 6 pressed against the inner end of the tube 14 so as to make a gas-tight joint.

The magnet-coils and their cores, which are all inside of the casing 2, form, together with the iron casing, a magnetic field of the same general nature as that of a bipolar electric generator of the more usual form. These parts are shown in Fig. 149. The coils 19 and 20, together with their cores and pole-pieces 21 and 22, are fastened to the casing 2 by the capscrews 18 which

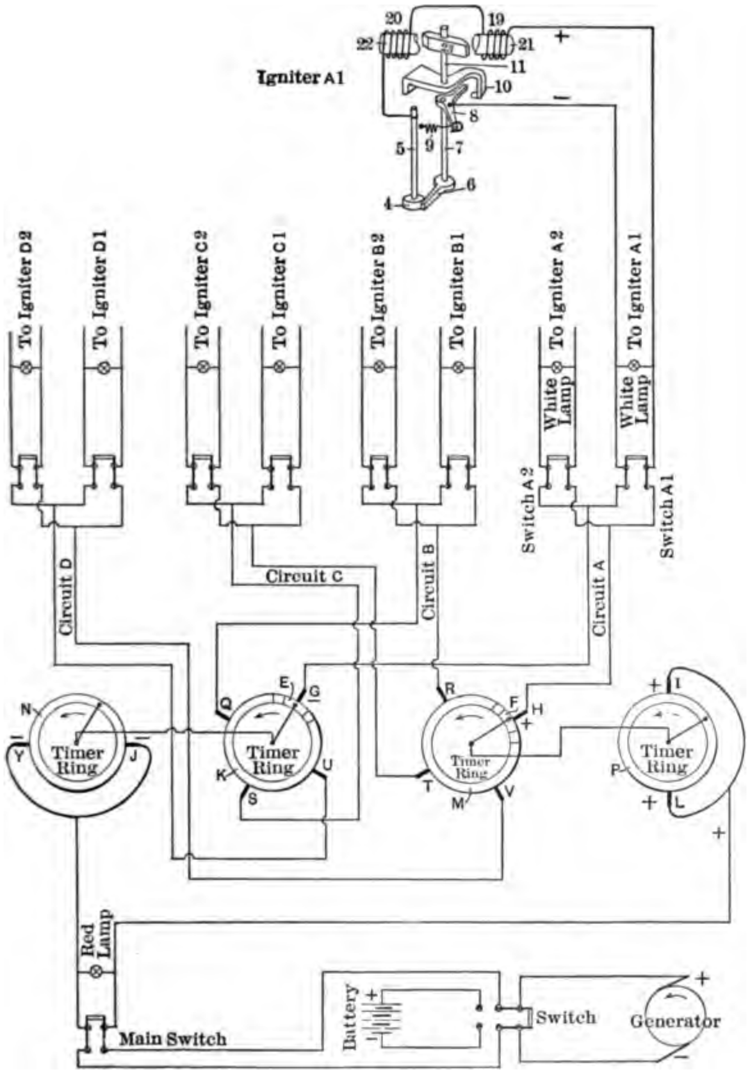


FIG. 150. (*See also* Figs. 146, 147, 148, and 149.)

Connections for Four-ring Timer and Eight Electromagnetic Igniters, Two in **Each** of Four Combustion Chambers of One Engine.

are threaded into the magnet-cores. A magnet-armature 23 of mild steel is rigidly mounted on the same spindle 11 that has the hammer 10 rigidly fastened to it. The magnet-armature occupies part of the space between the pole-pieces of the magnets.

The action of the igniter can be understood by referring to its skeleton representation in Fig. 150. The positions of the moving parts there correspond to those when no current is passing through the igniter. The movable ignition-point is shown pressed against the stationary one by the effort of the coiled tension spring 9. The hammer 10 is rotated back clear of the anvil arm on 8. The magnet-armature has its length at a considerable angle with the center line of the two magnet-cores.

The path of the current, when one is flowing through the igniter from the positive (+) side of the connecting wire, is through coil 19 to and through coil 20 to the outside terminal of the stationary electrode 5-4, to the movable electrode 6-7 and the arm 8, from which it leaves the igniter through the negative (−) connection. As soon as a current starting through the igniter gives the magnets sufficient strength, the armature 23 is rotated by magnetic action, in the direction to bring its length more nearly parallel with the axis of the magnet-cores. The armature rotates the spindle 11 and the hammer 10 with it, since they are all fastened rigidly together. The hammer strikes the anvil arm which is the rear portion of 8 and moves it slightly so as to rotate the movable electrode and separate the ignition points between which an arc is drawn at the instant of their separation. As soon as the arc breaks down and the current discontinues, the tension spring 9 draws the movable electrode back against the stationary one again and at the same time rotates the hammer 10 and magnet-armature 23 back to the positions shown. The armature is shown rotated more out of line with the magnet-cores than really occurs, this being done in order to make the drawing clear. An examination of Fig. 149 will give an idea of how far the armature and hammer rotate back.

Igniters of the form just described have been constructed in large sizes for use on 80-volt current.

134. Wiring Diagram for a Four-ring Timer and Igniters Actuated by a Rotary Magnet-Armature. — Fig. 150. This wiring diagram is for a timer like that shown in Fig. 146, and for eight igniters like that of Figs. 147, 148, and 149, two igniters in each of four combustion chambers. The descriptions of the timer and igniter cover practically all of the wiring diagram except the source of electric supply.

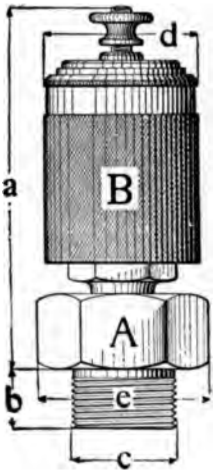
A generator and a battery are represented for supplying current to the system. Either may be thrown into circuit by the double-pole double-throw switch near the generator. If a storage battery is used, it must be charged from some source other than the generator shown, unless additional connections are made for this purpose. Most of the arrangements of generators and batteries which have been shown in connection with mechanically operated igniters can be used instead of the generator and battery shown in the diagram. It should be remembered, however, that no kick-coil is required in connection with electrically operated igniters.

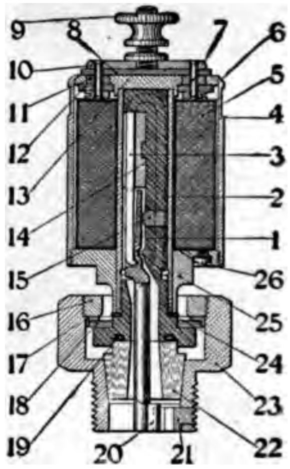
135. Igniter with Vibratory Magnet-Armature. — The small magnetic plug shown in full view in Fig. 151 is of a size suitable for use on automobile and small boat motors. The length over all is slightly less than 4 inches, and the diameter of the cylindrical portion which incloses the magnet-coil is about $1\frac{5}{16}$ inches. The plug is shown in longitudinal section in Fig. 152. The movable electrode, the magnet-core, and the U-shaped spring which presses the movable electrode against the stationary one, are shown in Fig. 153.

The movable contact-point 20 at which the ignition arc is drawn is at the lower end of the movable electrode 1-20, whose flattened upper end 1 is the armature of the magnet. The U-shaped spring 3 presses the movable electrode against a blunt knife-edge which is part of the magnet-core, or "pole-piece," 2, and keeps the movable contact-point 20 pressed against the stationary contact-point 21, except while these points are separated to draw an ignition arc. The ends of the U-shaped spring are slightly nearer the ignition-points than the knife-edge is.

The path of the current through the plug, assuming a direction

of flow for convenience, is from the terminal 9 through the plate 10, rivet 7, ring 6, magnet-coil 5, screw 26, body of the upper portion of the plug, movable electrode 1-20 to the stationary electrode 21, which makes electric connection with the metal of the motor. The screw 26 is one of the terminals of the magnet-coil, and has metallic contact with the upper body of the plug. All of the upper body of the plug is insulated from the stationary





FIGS. 151 and 152. (*See also* Fig. 153.)

Small Electromagnetic Low-tension Igniter Plug. Bosch Magneto Company, New York.

a = 90 millimeters. d = 37 millimeters.
b = 15 millimeters. e = 44.5 millimeters.
c = ¾-inch gas-pipe thread.

ignition-point 21 and the hexagon-head screw-plug 23 by means of the steatite cone 22 and the mica rings, or "plates," 18.

As soon as the current through the plug attains sufficient volume, the upper end 1, of the movable electrode 1-20, is attracted toward the magnet-core 2. This causes the movable electrode to rock on the supporting knife-edge and thus separate the ignition-points 20 and 21, so that an electric arc is drawn between them. The electromagnet acts as a kick-coil to produce an arc suitable for ignition. The brass piece 15 prevents the

upper end 1 of the movable electrode from being drawn into contact with the steel of the magnet-core, which action, if not prevented, would probably cause the two parts to cling together longer than allowable for the operation of the igniter at high speed of the motor.

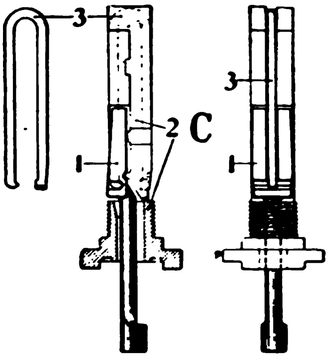


FIG. 153.

Details of Magnet-Core, Movable Electrode, and Spring of Figs. 151 and 152.

FIGS. 152 and 153.

1. Rocking electrode.
2. Magnet-core or pole-piece.
3. U-shaped spring.
4. Iron sleeve.
5. Magnet-coil.
6. Current conducting ring.
7. Current conducting rivet.
8. Mica disk.
9. Terminal nut.
10. Current conducting plate.
11. Insulating bush.
12. Mica ring.
13. Upper yoke of magnet.
14. Detachable brass piece.
15. Separating brass piece.
16. Internal ring-nut.
17. Centering ring.
18. Mica rings.
19. Packing ring.
20. Movable ignition-point.
21. Stationary ignition-point.
22. Steatite insulating cone.
23. Hexagon head with thread of plug.
24. Packing ring for coil body.
25. Lower yoke of magnet.
26. Connecting screw at end of magnet winding.

This plug should be operated in a vertical position, with the terminal 9 at the top. The motor cylinder should be well cooled at the time of screwing the plug into it, and the air-current for cooling the motor should strike the plug. The upper body of the plug must not touch the metal of the motor, since it must be electrically insulated from the motor and the metal of the car.

The plug can be taken apart for examination and cleaning by unscrewing the coil body from the magnet-core, or "pole-piece." The U-shaped spring can then be pressed upward by means of some small tool such as a screwdriver or knife-blade, until the crown projects far enough to be grasped for completely removing the spring. The brass piece 14 can then be removed, after which the removable electrode can be taken out. If the coil body does not unscrew readily, kerosene put into the groove at the top of the screw-plug will loosen the threads.

136. Magneto and Wiring Diagram for Magnetic-plug Ignition System. — Fig. 154 shows the electric connections between

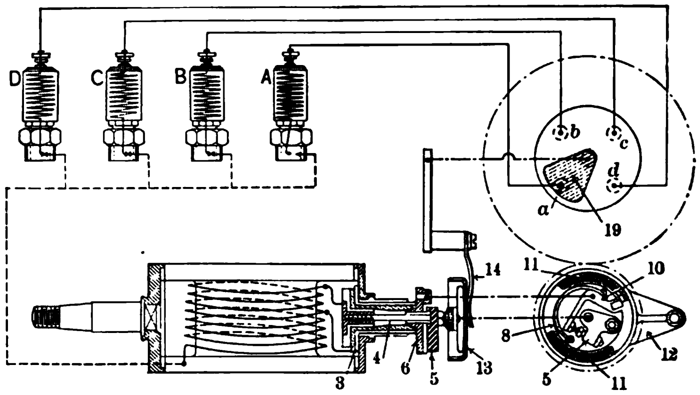


FIG. 154. (*See also* Figs. 151, 152, 153, 155, and 156.)
Magnetic-plug Ignition System for Small Motors with Four Combustion Chambers. Bosch Magneto Company, New York.

FIGS. 154, 155, and 156.

1. Permanent field-magnets.
2. Armature.
3. Flanged tube to which junction of main and auxiliary windings is connected.
4. Fastening screw for contact-breaker or interrupter.
5. Contact-piece on interrupter.
6. Interrupter-disk.
7. Long platinum contact-screw.
8. Spring acting on interrupter-lever.
9. Short platinum contact-screw.
10. Interrupter-lever.
11. Segments on timing-lever.
12. Timing-lever.
13. End cap over interrupter.
14. Spring for holding end cap.
15. Conducting rods on distributer.
16. Carbon brush of distributer.
17. Distributer disk insulation.
18. Connection terminals.
19. Rotating arm of distributer.
20. Dust cover.
21. Fastening nuts for distributer disk.
22. Short-circuiting terminal.
23. Connecting piece for end of auxiliary winding.

four magnetic plugs such as that described in the preceding section, and a magneto especially adapted to supplying current to such plugs. The plugs are lettered *A*, *B*, *C*, *D*. Only the parts of the magneto essential to showing the electric connections appear in the figure. They are illustrated in conventional form to some extent. The armature is shown in part longitudinal section at the middle lower portion of the figure. A mechanically operated interrupter is shown at the right-hand lower part of the illustration, and just above it is a distributer for directing the current to each of the igniter plugs in succession. The interrupter and distributer are shown as they appear when looking toward the end of the armature spindle. The bent interrupter-lever 10 and the contact-piece 5 rotate with the armature. The distributer arm 19 rotates about a center which is concentric with the center of the two large circles which surround it. As the distributer arm rotates it makes contact successively with the contact-pieces *a*, *b*, *c*, *d*. The distributer arm is shown in contact with *a* and the igniter *A* is operating. Each of the heavy dot-and-dash lines is to show electric connection either between the two views of the same part or between two parts which fit together so as to have electric connection. The heavy broken line with dashes all of the same length indicates ground connection between the magneto armature and the ignition plugs.

The magneto armature* is of the shuttle type and has two windings, one of which is a continuation of the other. These windings are illustrated diagrammatically by one coil of several turns. The lower portion of the coil may be called the main winding, and the upper portion the auxiliary winding. One end of the main winding (the lower end as illustrated) is connected to the core of the armature. The junction point of the two windings, which is an end of each winding, is connected to the flange 3 of an insulated tube which extends through the hollow spindle of the armature and has the interrupter-disk 6 fastened to its outer end. The interrupter-disk has a pin which carries the interrupter-lever 10. The latter has electric connection

* The constructive form of the magneto is shown in Figs. 155 and 156. Examination of these illustrations may give a clearer understanding of the diagram.

with the disk 6 and thence through the tube to the flange 3. The upper end of the auxiliary winding is connected to a long screw 4 which extends through the hollow armature spindle and the contact-piece 5 on the disk 6. The screw 4 and contact-piece 5 are electrically connected together, but are insulated from all other parts of the magneto except a carbon button (brush), mounted on a bow-spring, and pressed against the end of the screw 4. Electric connection is made between the button

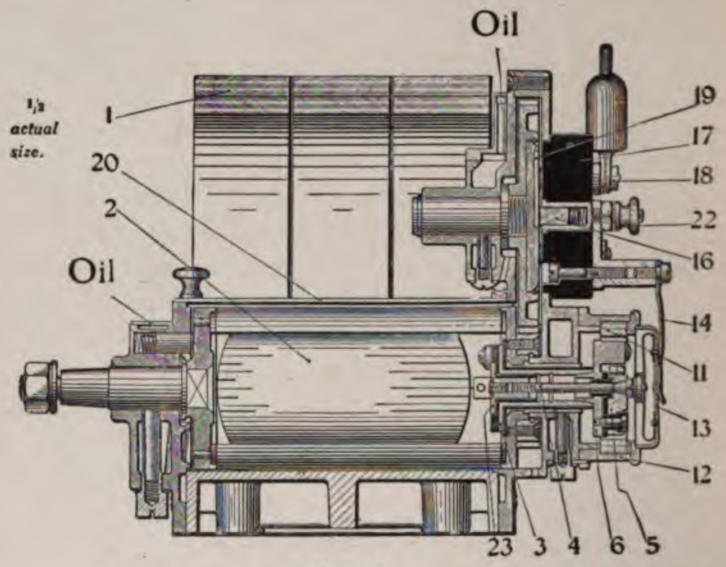


FIG. 155.

Bosch Magneto for Four Low-tension Magnetic Igniters. Longitudinal Section.

and the distributer rotor 19 by means of the clip-spring 14 and the other parts shown in conjunction with 14 in Fig. 154. As the contact-piece 5 and interrupter-lever 10, both mounted on the disk 6, as stated above, rotate with the magneto armature, a piece of insulating fiber in the end of one of the arms of the interrupter-lever (the right-hand end as shown) strikes the stationary segments 11, thus rocking the lever and causing the contact-point at the left-hand end of the lever to move away from the contact-piece 5. The contact-points of the interrupter are

pressed together by the spring during the time the fiber piece is not in contact with one of the two segments 11.

While the electric pressure and current are increasing in the magneto armature on account of its rotation in the magnetic field, the contact-points of the interrupter are kept pressed together by the spring 8. During this time the current divides itself between two electric circuits exterior to the armature windings. Part of the current flows through the closed interrupter, and the remainder through one of the igniters. The

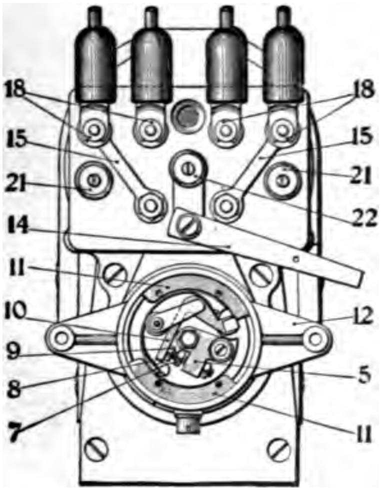


FIG. 156.

Interrupter End of Fig. 155. Interrupter Cover Removed.

amount of current through the igniter during this time is not sufficient to cause separation of the ignition-points, however. At, or about, the instant the current through the interrupter attached to the armature spindle attains its maximum value, the interrupter circuit is broken at the contact-points of the interrupter. The interrupter is shown in its position just after its circuit has been broken by the striking of the piece of fiber against the upper stationary segment 11, the rotation of the interrupter being counter-clockwise (left-hand). The consequent sudden stoppage of the current flowing through the inter-

rupter and auxiliary winding of the magneto armature causes a correspondingly sudden increase of voltage in the winding of the armature and of current through the ignition plug. The increased current through the igniter causes the ignition-points to separate so that an arc is drawn for ignition. The igniter *A* is shown operating, the distributer arm being in contact with the corresponding contact-piece *a* of the distributer.

Two electric impulses per revolution of the armature are generated in it, since the armature is of the shuttle-wound type rotating in a bi-polar field. In order to deliver current once to each of the four igniters, the armature must make two revolutions and the distributer must make one revolution. The distributer arm is driven by a pair of tooth-gears, one on the armature spindle and the other on the distributer shaft. The pitch circles of these gears are represented by the dash-and-dot circles which touch each other. The gear on the igniter shaft has twice as many teeth as the one on the armature spindle. The rotative speed of the distributer gear is therefore half that of the armature gear. The latter is the driver.

The timing-lever 12, to which are attached the segments 11, can be rocked about the armature spindle to vary the time of ignition — to advance or retard the spark.

The constructive form of the magneto with an interrupter for operating four electromagnetic igniters is shown in Figs. 155 and 156. The former is a longitudinal section, and the latter is an end view with the cover cap of the interrupter removed, the spring which holds the cover cap being pushed to one side. The following description is supplementary to that which has just been given. The cover cap 13 has fastened to it a bow-shaped spring (not numbered) which carries a carbon button (not numbered) that presses against the outer end of the screw 4. The latter is connected to the end of the auxiliary winding of the armature. By this means the cap 13 is placed in electric connection with the auxiliary winding. The cap is insulated from the contact-breaker. The spring 14, which holds the cap in place, connects electrically with the central carbon 16 of the distributer. This carbon is in contact with the distributer arm

19 and also with the terminal 22. The four contact-pieces (*a*, *b*, *c*, *d* in Fig. 154) are connected to the four terminals 18, one to each terminal. From these terminals the wires lead to the igniter plugs. The path of the current from the armature winding of the magneto to the igniter plugs, when the interrupter circuit is open, is through the screw 4, carbon button and bow-spring to the cap 13, thence through the spring 14 and its fastenings to the central carbon 16, distributer arm 19, thence to one of the terminals 18 whose contact-piece the distributer touches at the moment, to the igniter, and then back through ground to the armature of the magneto, or in the opposite direction. The current flows first in one direction and then in the opposite through this path, since the magneto produces an alternating current.

In order to have a convenient means to cut out the ignition while the magneto is running, the short-circuiting terminal 22 is provided. When this terminal is connected to ground, as through a wire and switch, the closing of the switch diverts the current from the igniters so that ignition ceases.

CHAPTER XV.

TRANSFORMER SPARK-COILS AND SYNCHRONIZER, OR MASTER, TREMBLER-COILS.

137. General. — The purpose of the transformer spark-coil in connection with high-tension ignition is to transform electricity of low pressure into electricity having a pressure high enough to cause it to jump across the space between metallic parts when the space contains a mixture of air and fuel in the state of gas or vapor. The low-pressure primary current which the transformer receives rarely has a pressure greater than 10 volts. The secondary current which the transformer delivers has a pressure of several thousand volts. The amount of electricity decreases during the transformation, to an extent somewhat greater proportionately than the pressure increases.

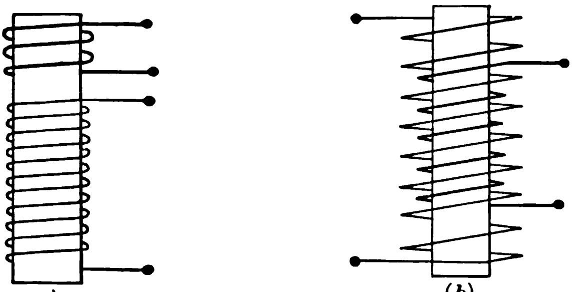
In order to cause the transformer spark-coil to operate, electric current is first sent through it and then interrupted. The device for interrupting the current is sometimes part of what is broadly known as the transformer spark-coil. In other cases the interrupter is separate from the spark-coil, so far as mechanical connections are concerned. The separate interrupter may be either mechanically operated, or it may be a coil similar in a general way to a kick-coil (single winding) provided with an electrically operated interrupter. The latter is generally called a master trembler-coil, a master vibrator-coil, or a synchronizer coil.

138. Elementary Transformer Spark-Coils. — In its more usual form, the transformer spark-coil consists essentially of a core in the form of a bundle or sheaf of small soft iron or mild (soft) steel wires, a primary winding of insulated copper wire, and a secondary winding, also of insulated copper wire. There is generally a tube of some thin strong insulating material between the core and the windings. This tube, together with

insulating washers, or rings, at its ends, forms a spool for retaining the windings in place. Some thin insulating material is generally placed between the two windings to keep them separated from each other.

The primary winding, which is next the core, consists of some 200 to 300 turns of comparatively thick copper wire around which is wrapped cotton or silk thread for insulating it. The secondary winding consists of some 1500 to 2000 turns of thin copper wire insulated in the same manner as the wire of the primary winding. The secondary winding is practically always wound outside of the primary winding.

In some transformer coils all four of the ends of the windings are brought out separately; in others two of the wire-ends are



(a) (b)

FIG. 157.
Four-terminal Winding of Transformer Spark-Coils. Conventional Representations.

connected together, an end of the primary to an end of the secondary, and only one wire brought out from this junction of the two windings. In the latter winding, the coil has only three terminals, and the two windings are in one sense continuous. Whether the two windings are kept separate and all four of the wire-ends brought out as terminals, or the windings fastened together end to end and only three terminals brought out, depends chiefly on the nature of the ignition system in which the coil is intended to be used, as will appear later.

It may be noted that a transformer coil can generally be

.dily distinguished from a kick-coil for low-tension ignition, the difference that the transformer coil has either three or ur terminals, while the kick-coil has only two terminals unless is of unusual design for some special purpose.

Some of the conventional methods of representing the core and windings of transformer spark-coils are shown in Figs. 157 and 158. In Fig. 157 the primary and secondary windings are not connected together, consequently four terminals appear in both (*a*) and (*b*), these being two conventional methods of representing this type of winding. In (*a*) the primary winding is represented at the upper end of the core, and the secondary

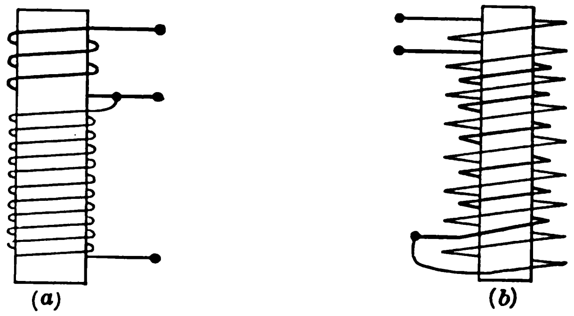


FIG. 158.
Three-terminal Winding of Transformer Spark-Coils. Conventional Representations.

winding at the lower portion. In (*b*) the primary winding is represented next to the core, and the secondary winding outside of the primary. In Fig. 158 the primary and secondary windings are connected together, thus leaving only three terminals. Otherwise these conventional representations are similar to those of the preceding figure.

139. Operation of Elementary Transformer Spark-Coil withou Trembler. — A plain transformer spark-coil is shown connecte to an electric battery in Fig. 159. Four different arrangemen of the connections are shown, including the different locatic of the break in the connecting wires. If in any of these arran ments the ends of the wires are pressed together at the br so as to close the primary circuit, a current will flow from

y through the primary winding of the transformer. Then ıarating the wire-ends at the break so as to interrupt the .t suddenly, a spark will be caused to jump across the gap in the secondary circuit. If the wire-ends were separ very slowly so as to draw an arc between them and thus a gradual decrease of the primary current, no spark would

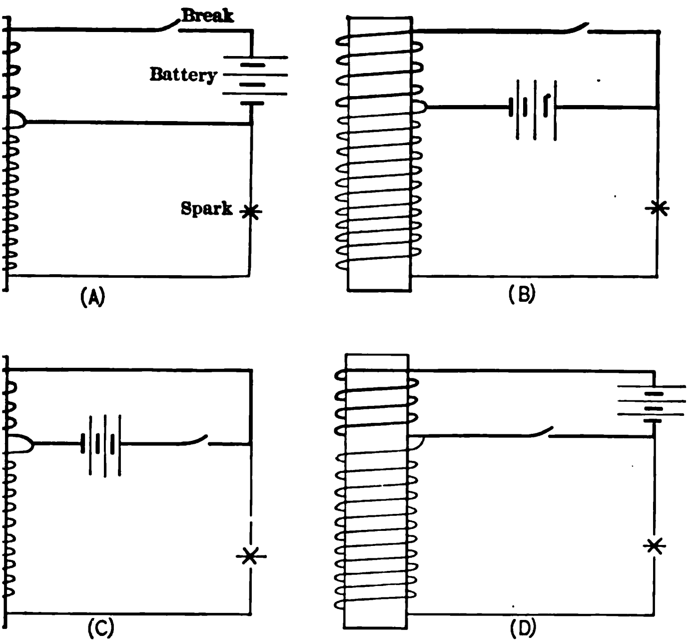


FIG. 159.

Various Connections of a Transformer Spark-Coil and a Battery.

at the spark-gap. Sudden interruption of the primary t is requisite to the production of a jump-spark. No appears at the spark-gap at the instant of closing the y circuit. This refers to such transformer coils as are ıarily used for ignition purposes, and when the primary t is not greatly in excess of what it should be. If an ve current is sent through the primary of the transformer, he use of too many cells in series in a battery, it is possible

to produce a spark sometimes at the instant of closing the primary circuit.

The operation of the transformer more in detail is as follows: The current in the primary winding magnetizes the iron or steel core of the transformer. Then as the primary current ceases suddenly, the core loses its magnetism rapidly. This rapid decrease of magnetic flux through the core and also through the secondary winding, since the core passes through the secondary, induces electromotive force in the secondary. The secondary circuit being open at the spark-gap, this induced electromotive force builds up a pressure in the secondary until the difference of potential between the two sides of the spark-gap causes a spark to pass across the spark-gap.

The circuit of the high-tension current embraces different elements, or combinations of elements, in the four arrangements of Fig. 159. The spark-gap is of course always included in the high-tension circuit. The following refers to the high-tension current that is induced by the interruption of the primary current, and which flows while the primary circuit is open. In (*A*) the high-tension current flows through the secondary winding only; in (*B*) it flows through the secondary winding and the battery in series; in (*C*) through the secondary and primary windings in series; and in (*D*) the secondary current flows through the secondary and primary windings and the battery in series.

Any of the above arrangements of the spark-coil, battery, and break in the primary circuit will operate satisfactorily for ignition purposes, but it is probable that (*A*) and (*B*) are the best.*

140. Trembler Transformer Spark-Coil. — In Fig. 160 a trembler, or vibrator, interrupter and a condenser are shown in connection with a transformer spark-coil and an electric battery. The trembler is a steel spring *V* rigidly fastened at one end to the metal block *A*. The spring has fastened to it a contact-piece *M* which is pressed against a mating contact-piece *K* by

* This last sentence does not apply to transformer coils in which there is not such great difference in the number of turns in the two windings. Coils used for medicinal purposes and physical treatment are generally of the latter class.

the elastic action of the spring. *K* is shown in the form of an adjusting screw held in place by the rigid metal part *B*.

The action of the trembler is as follows: Immediately upon closing the primary circuit, as by pressing the wire-ends together at the break in the battery circuit, current begins to flow through the interrupter and the primary winding of the transformer in series. The path of the primary current is from the positive (+) side of the battery to and in series through *B*, *K*, *M*, *V*, *A*, the primary winding and back to the negative (−) side of the

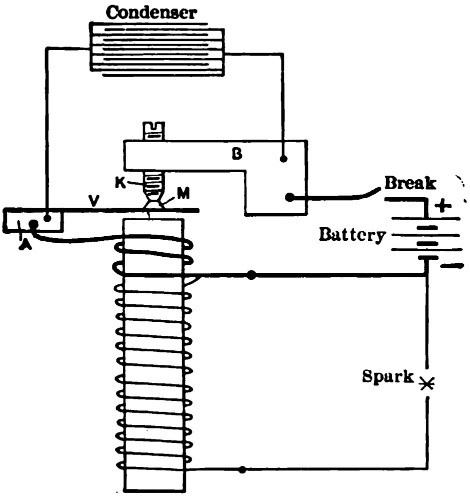


FIG. 160.
Trembler Spark-Coil Connected to a Battery and a Spark-Plug. Requires both Sides of Timer to be Insulated. Unbroken High-tension Circuit.

battery. As soon as the transformer core becomes sufficiently magnetized by the action of the current, the core attracts the free end of the trembler away from the stationary contact-piece *K*, thus separating *M* and *K*. This breaks the circuit at the trembler contacts and interrupts the flow of current through the primary winding. As soon as the current stops flowing, the magnet core loses magnetism to a sufficient extent to allow the end of the spring to move away from it and again press the contact-pieces together. This closes the primary circuit so that

current begins to flow through it again, and the same operation is repeated as long as the wire ends are kept pressed together at the break. A spark passes at the spark-gap each time the current is interrupted at the contacts of the trembler. The trembler spring is not allowed to move far enough to touch the end of the magnet-core, since it would tend to cling to the core. The spring may be strong enough to keep it from being drawn against the core, or a stop of some non-magnetic substance such as wood, rubber, or brass may check its movement toward the core.

The adjustable contact-screw *K* affords a means of setting the interrupter so as to secure the most satisfactory operation, and of taking up wear at the contact-points on account of sparking and burning. This is the only adjustment in numerous makes of spark-coils. Others have a second means of adjustment, as will appear later. Ordinarily the most desirable setting of the adjustment means is that at which the least amount of current is required in connection with sufficiently rapid vibration of the trembler.

The **condenser** prevents excessive sparking and burning at the contact-points of the trembler, and adds to the efficiency of operation of the transformer. It consists of numerous sheets of tin-foil laid together with thin sheets of insulating material, such as mica or varnished paper, between them. Each second sheet of foil projects beyond the insulation at one edge, and the remaining (alternate) foil sheets all project in the same manner at the opposite edge. The foil-sheet edges which project next to each other are all pressed together so as to make electric connection between them, this set of sheets forming what is called one side of the condenser. The remaining foil sheets, whose edges project in the opposite direction, have their projecting edges pressed together in a similar manner, this second set of sheets forming the other side of the condenser. This disposal of the foil sheets is shown diagrammatically in the figure, but the insulating sheets between the foil are not shown. The condenser is connected to *A* and *B*, which are on opposite sides of the contact-points *K* and *M*. The condenser is thus placed in parallel with the interrupter.

During at least the first part of the separating movement of the trembler spring, the current tends to keep flowing across the gap thus formed between the contact-points of the trembler. If there is no condenser, or if it is inoperative, the arc drawn between the contact-points soon burns and destroys the contact-points at the trembler. But when the condenser is operative, the current, instead of maintaining an arc at the contact-points, is diverted into the condenser, thus charging the condenser. The sparking and burning at the contact-points is thus kept down to an amount so small that but little harm is done to the points. The current ceases to flow into the condenser soon after the trembler contacts begin to separate, and the condenser then immediately discharges back through the primary circuit while the circuit is still open at the contacts. On account of the momentum of the discharge current, the condenser immediately becomes again charged to a less extent with its polarity reversed, then discharges in the opposite direction, and so on as the electricity continues oscillating. This oscillation of the electricity through the primary winding produces a rapid series of sparks at the spark-gap in the secondary circuit. This series of sparks, occurring during one separation of the trembler contacts, is ordinarily referred to as a single spark.

The current does not flow *through* the condenser.

There is always a complete metallic circuit, exclusive of the spark-gap, for the high-tension current in Fig. 160. This is also true of Fig. 161, which differs from the preceding figure in having the trembler support connected to the junction of the two windings instead of to the end of the primary winding.

In Figs. 162, 163, 164, and 165, which show different arrangements of the battery and connections, there is always a complete circuit, exclusive of the spark-gap, for the secondary current. This circuit includes the battery in each case. It is not objectionable to have the high-tension current flow through the battery, however.

All of the arrangements of the parts as shown in the last four figures are commonly used in ignition systems. The arrangements shown in Figs. 160 and 161, although entirely correct so

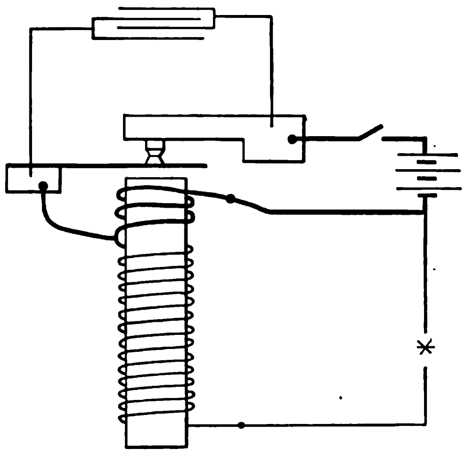


FIG. 161.

Same as Fig. 160, Except the Connections to the Primary Winding of the Spark-Coi

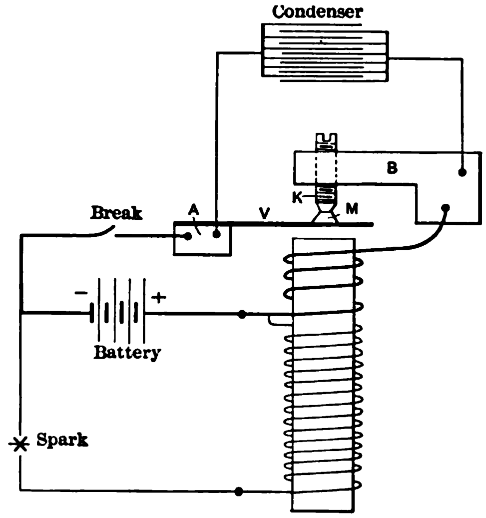


FIG. 162.

Trembler Transformer Connected to a Battery and a Spark-Plug so that One Sid of the Timer can be Grounded. Unbroken High-tension Circuit.

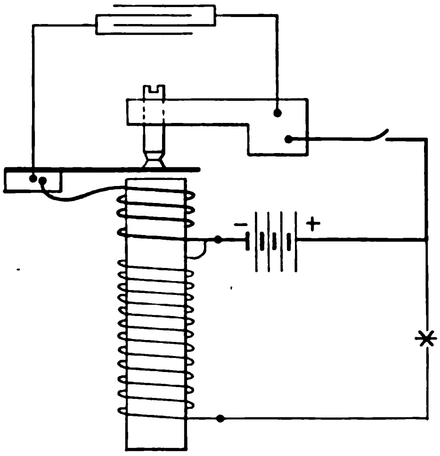


FIG. 163.

bler Spark-Coil, Battery and Spark-Plug Connected so that One Side of Timer can be Grounded and the Secondary Circuit is Unbroken.

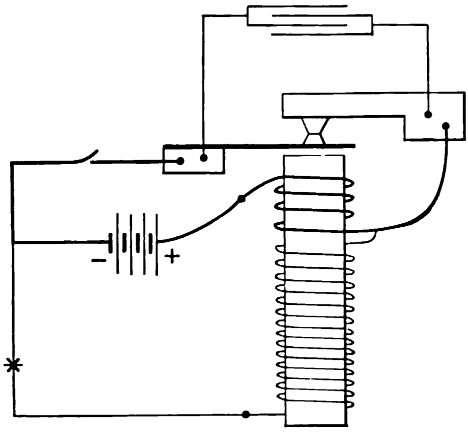


FIG. 164.

Connections Giving Same Conditions as Stated under Figs. 162 and 163.

far as the spark-coil and battery are concerned, are not so much used on account of requiring a form of timer that is more expensive to construct than that which can be used with the four figures which follow these two.

At least some of the most prominent makers of spark-coils think that a high-tension trembler spark-coil should not be connected to the other parts of an ignition system in such a manner that the high-tension current must pass through the

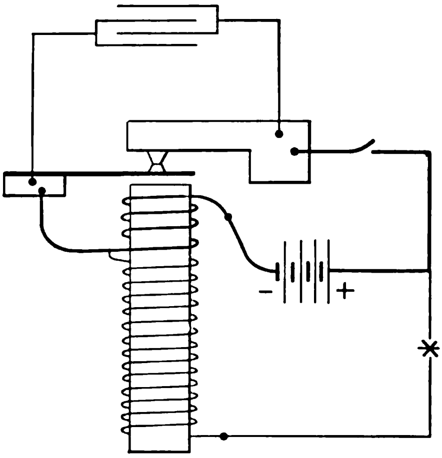


FIG. 165.
Connections Giving Same Conditions as Stated under Figs. 162 and 163.

trembler contacts of the spark-coil as a part of the only available high-tension circuit during part of the time. Arrangements under which this condition may occur are shown in Figs. 166, 167, 168, and 169. Thus, in any of these arrangements, if the wire-ends are suddenly separated at the break while the trembler is operating, the breaking of the circuit may occur at the same instant at both the break in the wire and at the trembler. This leaves no metallic circuit for the high-tension current. The tendency of the high-tension current is then to jump the gaps at the trembler and at the break in the primary circuit. If the resistance of these gaps is high at the instant, an excessive electric pressure will be brought to bear on the condenser and may break

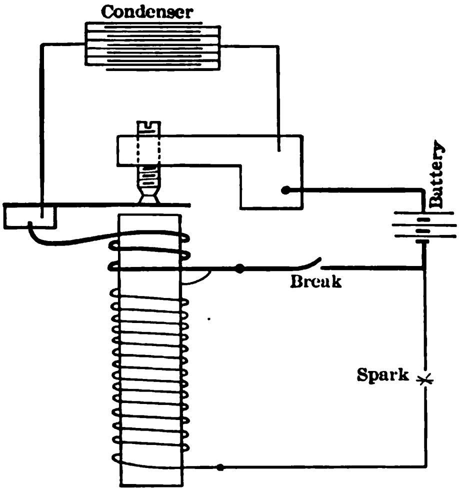


FIG. 166.
rembler Spark-Coil, Battery and Spark-Plug Connected so that the High-tension Circuit is Interrupted. One Side of the Timer can be Grounded.

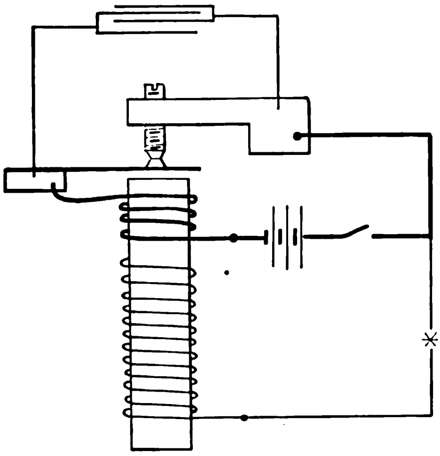


FIG. 167.
Connections Giving Same Conditions as Stated under Fig. 166.

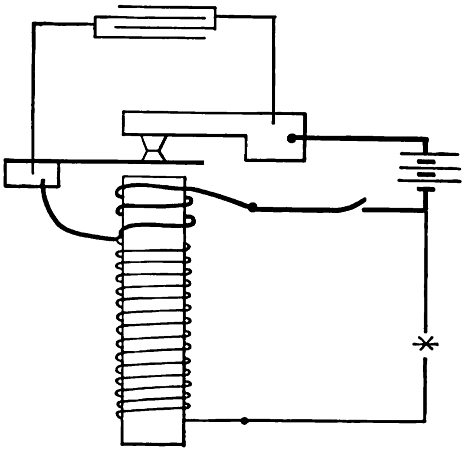


FIG. 168.
Connections Giving Same Conditions as Stated under Fig. 166.

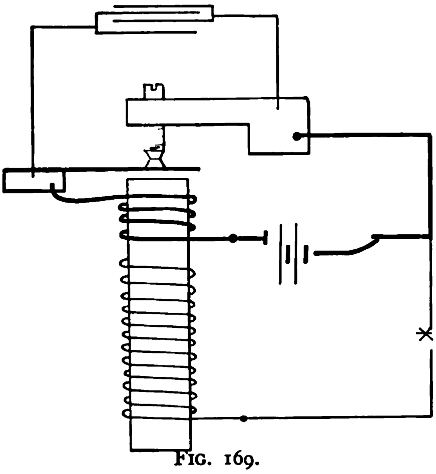


FIG. 169.
Connections Giving Same Conditions as Stated under Fig. 166.

n its insulation. Such an injury to the condenser will of se interfere with the operation of the spark-coil.

1. **Safety Spark-Gap.** — In order to protect the windings he spark-coil against unduly high electric pressure, a safety k-gap is generally used in connection with the other parts ıe spark-coil. Such a safety gap is shown in Fig. 170. As e shown, the safety gap is between the pointed edges of two es of metal, each of which is connected respectively to an

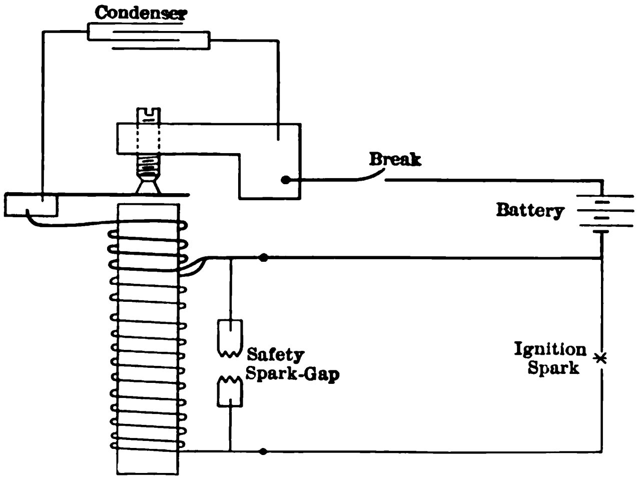


FIG. 170.

Shows Safety Spark-Gap for Protecting Winding of Spark-Coil.

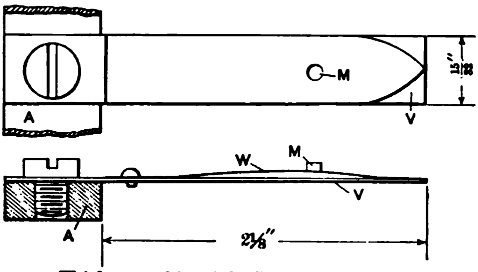
of the secondary winding. If the connections leading to gnition spark-gap are removed, thus destroying the regular ıit for the high-tension current, sparks will jump across the y gap during the operation of the spark-coil. If there were afety gap, there would be danger of the pressure becoming enough to break down the insulation of the transformer ling. The safety gap is made wide enough to prevent sparks ing across it during the time the igniter is connected into circuit. Half an inch or somewhat less is the ordinary h of the safety gap on a trembler spark-coil. Each side of gap may have either one or more points. It is sometimes

placed inside the casing which contains the transformer and condenser, sometimes outside of the casing so as to be plainly visible.

142. Lag of Spark-Coils. — Between the instant of the closing of the primary circuit and the jumping of the spark in the secondary circuit (at the spark-plug) of a trembler spark-coil, an interval of time elapses which is appreciable in comparison with the length of time occupied by one revolution of a high-speed motor, and decidedly more appreciable in comparison with the allowable variation in the time of ignition as related to the position of the motor piston during its movement. A certain amount of time is required for the primary current to attain its final strength in the primary winding, and for the steel core of the coil to become sufficiently magnetized to attract the trembler forcibly enough to just begin to move it. This may be called the magnetic lag of the spark-coil. Then, after the magnetism has become sufficiently strong, more time is required to move the trembler far enough to interrupt the primary current. The latter may be called the mechanical lag of the spark-coil. It might be added that still more time is required to induce the current in the secondary after the primary is interrupted, remembering that the current is at first diverted into the condenser, but this time is almost inappreciable in comparison with that which has been mentioned.

143. Tremblers, or Vibrators: Bow-spring, Hammer-break, and Plain Types. — In order to have satisfactory operation of a transformer spark-coil with a trembler interrupter, it is necessary that the trembler respond promptly to the magnetic attraction of the magnet-core, that the contact-points separate rapidly, and that the contact-points make constant and firm contact during the time they are intended to be pressed together between each two successive vibrations of the trembler. The promptness of response to the magnetic attraction of the core is more especially essential to satisfactory operation in connection with motors which rotate at high speed. The above features are generally secured by means of a compound trembler of either the " bow-spring " type or the " hammer-break " type.

A **bow-spring trembler** is shown in Fig. 171. The straight spring *V* is rigidly held at one end by the metal block *A* to which it is fastened by a screw. A thin bow-shaped spring *W* is fastened at one end to the spring *V* by means of rivets near the



Thickness of Straight Spring = .022 Inch
" " Bow " = .008 "

FIG. 171.

Bow-spring Trembler Blade for Spark-Coil. The Autocoil Company, 136 Seventh Street, Jersey City, New Jersey.

supporting block *A*. The bow-spring carries the contact-piece *M* at which the circuit is broken by the vibration of the trembler during the operation of the interrupter.

In the standard size of this type of trembler, the dimensions are:

Width of both springs	$\frac{15}{32}$ inch.
Thickness of straight spring	.022 "
Thickness of bow-spring	.008 "
Free length of straight spring	$2\frac{1}{8}$ inches.

In a smaller size of this trembler, made to meet conditions where the space is cramped, the free length of the flat spring is $1\frac{3}{4}$ inches. This shorter blade is considered by the manufacturer as inferior to the one of standard length.

A spark-coil whose interrupter has a bow-spring trembler of the above form is shown in Figs. 172 and 173. (The safety spark-gap appears plainly in the last figure.)

In the operation of the bow-spring trembler, the straight spring is first drawn down a slight distance by the attraction of the magnetized core of the spark-coil while the elastic action

of the bow-spring still keeps its contact-point pressed against the stationary contact-piece. The contacts then separate rapidly as the straight spring continues moving toward the magnetized core. When both blades spring back again after the core loses its magnetism, the elasticity of the very thin bow-spring is effective in keeping the contacts together, which might not be true if there were only one spring with the contact-point on it. In

FIG. 172.
Trembler Spark-Coil with Inclosing Case. Autocoil.

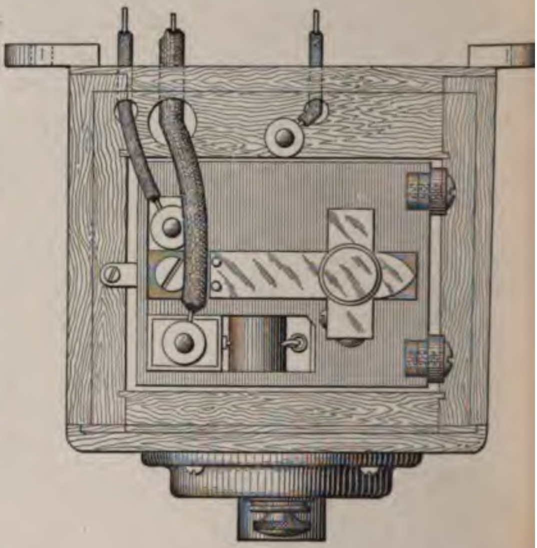


FIG. 173.
Top, or End, of Trembler Spark-Coil with Switch. Autocoil.

the latter case the secondary vibrations of the spring while the core is not magnetized between successive breaks in the circuit have a tendency to cause slight (undesirable) separations of the contact-points. The momentum gained by the straight spring before the contact-points begin to separate provides sufficient force to pull the contacts apart in case of any ordinary amount of burning and fusing at these points. The bow-spring trembler described above has been found satisfactory during extensive use.

A hammer-break trembler interrupter is shown in Fig. 174 in connection with the adjacent end of the coil box. The flat steel blade *V* is riveted to a short flat spring *U* which is rigidly supported at the opposite end by the stationary metal piece *A* so as to stand opposite the end of the magnetic core *E*. A contact-spring *W* carries the movable contact-piece *M* near one end and is rigidly supported by *A* at the opposite end. The contact-spring is very thin and flexible. It is sometimes made of copper. The steel trembler carries a hammer *H* whose striking flange

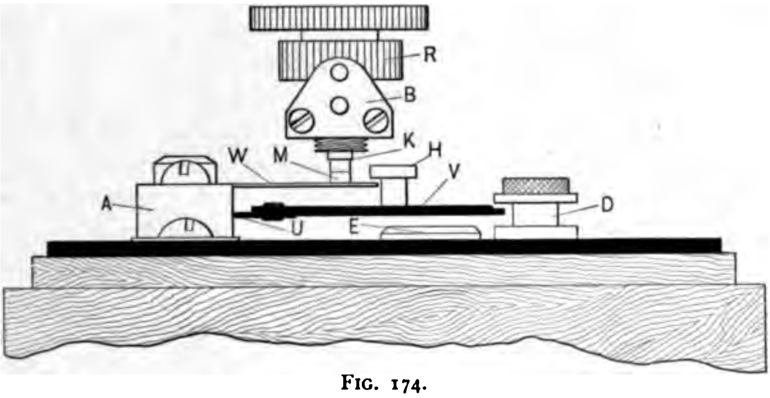


FIG. 174.
Bogert Hammer-break Trembler for Spark-Coil, C. F. Splitdorf, New York City.

stands slightly away from the free end of the contact-spring when no current is passing through the spark-coil. This allows a slight movement of the hammer and steel blade toward the magnet without moving the contact-spring and the attached contact-point *M*; further movement causes the flange of the hammer to strike the free end of the contact-spring and carry it, together with the contact-point *M*, along during the remainder of the movement toward the magnet, thus separating the contact-points. Since the steel blade and its hammer attain considerable speed before the hammer strikes the contact-spring, a rapid separation of the contact-points is effected. The hammer-blow is also effective in breaking apart the contact-points in case they become stuck together by fusing. The contact-spring, being light and thin, maintains good contact between the contact-points

while the hammer is not touching it. The movement of the hammer-blade *V* is limited in both directions by the hammer-stop *D*. The stationary contact-point *K* is in the end of an adjusting screw with a knurled head and a ratchet *R* against which a stop is pressed by a spring so as to prevent the screw from turning of its own account. The stop is carried by the stationary part *B*.

FIG. 175.
Laboratory Type of Spark-Coil, Splitdorf.

A spark-coil with a hammer-break trembler interrupter similar to the one just described is shown in Fig. 175. The box, or casing, inclosing the transformer in this figure is of the type generally used for ignition in stationary motors or for laboratory use. The high-tension terminals are shown on the top of the box, and the two low-tension terminals at the upper part of the front end.

Another type of **hammer-break trembler interrupter** is shown in Fig. 176. The trembler spring *W* is rigidly fastened at its

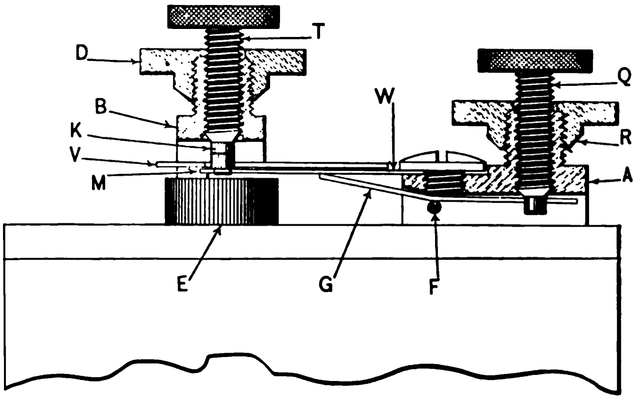


FIG. 176.
Hammer-break Trembler for Spark-Coil. Pittsfield Spark Coil Company, Dalton, Massachusetts.

right-hand end to the stationary metal block by means of a screw. The movable contact-piece *M* is fastened to the free

end of the spring *W*. A trembler blade *V* is riveted to the spring *W* at a point near the rigidly supported end of *W*. The movable contact-point *M* stands up through a hole in the trembler blade *V* so as to press against the stationary contact-point *K*. An auxiliary spring *G* presses against the under side of the trembler spring and is supported by a fulcrum *F*. An adjusting screw *Q* for regulating the pressure of the auxiliary spring against the trembler spring presses down against the right-hand end of the auxiliary spring *G*. The stationary contact-point *K* forms the point of an adjustable screw *T* which passes through the stationary metal part *B*. A lock-nut *D* serves to clamp *T* firmly in place. A similar lock-nut *R* answers the same purpose for the screw *Q*.

When no current is flowing through the spark-coil, the trembler spring *W* is pressed up so as to be slightly bent and thus cause the free end of the trembler blade *V* to be separated from it by a slight distance. When the trembler blade moves toward the magnet-core *E*, the contact-points remain together during the first part of the movement of *V* until *V* strikes the trembler spring *W*. The contact-points are then rapidly separated on account of the hammer-blow thus struck by *V* against *W*.

A plain single trembler interrupter is shown in Fig. 177. The trembler spring *V* is fastened to the stationary metal block *A*

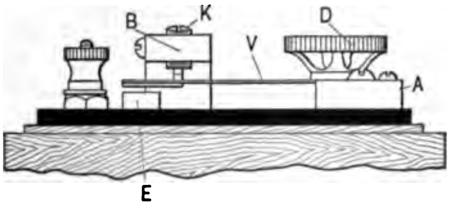


FIG. 177.
Trembler with a Single Blade. Splitdorf.

by small screws in such a way that the pressure of its contact-point against the end of the contact-screw *K* can be regulated by the adjusting screw *D* near the stationary end of the trembler blade. The contact-screw *K* is adjustable, but it is intended

that it shall be adjusted only to take up wear at the contact-points. The trembler spring has a small piece of soft steel fastened to its free end opposite the end E of the magnet-core. This soft steel armature is to cause the end of the trembler to be more strongly attracted toward the magnet-core than it would be without the armature.

144. Complete Trembler Transformer Spark-Coils. — A one-unit spark-coil for stationary or marine use is shown in Fig. 178. It has two low-tension terminals at the front end, and one high-tension terminal at the side. Fig. 179 is a one-unit coil intended

FIG. 178.
Marine Form of Trembler Spark-Coil.

FIG. 179.
One-unit Trembler Spark-Coil with Switch. Automobile Type.

for use on the dashboard of an automobile. The high-tension terminal is at the bottom of the box. It appears large on account of the insulating cap which covers it. There is a switch on the front of the box by means of which either of two batteries can be switched into circuit, or both cut out. This necessitates three low-tension terminals. Two of these are at the bottom, and the third at the top.

A two-unit dash coil of the same make as the last coil described is shown in Fig. 180 with one of the units removed from the outer casing. The two high-tension terminals are the large ones at the bottom. The switch at the front is for cutting in either of two batteries. There is a low-tension terminal at the

top of each unit, and two low-tension terminals at the bottom of the box. When a unit is placed in the outer casing, it auto-

FIG. 180.
Two-unit Trembler Spark-Coils with Switch. Automobile Type.

matically makes the electric connections necessary to complete the circuit inside of the outer casing. Fig. 181 shows a two-unit

FIG. 181.
Marine Type of Trembler Spark-Coils. Two Units. Heinze Electric Company, Lowell, Massachusetts.

marine or stationary spark-coil with two high-tension terminals at the top.

A four-unit dash coil is shown in Fig. 182. The switch at the front of the casing is known as a "kick-switch," since it can be operated by kicking (sidewise) the switch handle at the lower

part. When the small plug at the top of the switch is removed, the circuit is broken so that it is impossible to operate the spark-coils.

FIG. 182.
Four Spark-Coils Inclosed in a Case which has a Kick-Switch and a Removable Plug.

145. Synchronized Spark-Coils with Master Trembler. — It is sometimes difficult to adjust all of the trembler interrupters of a set of spark-coils so that the length of time which elapses between the instant of closing the primary (low-tension) circuit and the jumping of an ignition spark shall be the same for all coils of the set. Expressed otherwise, it is difficult sometimes to adjust the coils so that all of them shall have the same amount of lag. When the lag of the coils is unequal (in length of time), the ignition sparks do not jump at the right instant in all of the cylinders of the motor. Thus, in most motors of the usual types, the ignition should occur at regular time intervals. It does not so occur, however, if the spark-coils have different amounts of lag.

In order to obviate such an irregularity of lag in the ignition, only one interrupter is sometimes used for all of the transformer spark-coils. This interrupter is caused to operate by a single-wound electromagnet through which the low-tension current for all of the transformer coils passes. This single-wound coil

and its interrupter are together called a master trembler-coil, a master vibrator-coil, or a synchronizer coil. The transformer coils used in connection with a synchronizer coil either have no interrupters, or their interrupters are rendered inoperative, as by screwing down the contact-screw of each so that the contact-points are pressed firmly together and the trembler cannot vibrate, or by short-circuiting the tremblers with some electric conductor such as a piece of wire.

A four-unit set of spark-coils and a synchronizer for them are shown in Fig. 183. The synchronizer is in the left-hand end

FIG. 183.
Synchronizer Coil and Four Non-trembler Transformer Coils Inclosed in a Case which has a Hand-Switch.

of the outer casing. It is of practically the same shape and size externally as one of the transformer units. The connections are shown later.

146. Trembler Spark-Coil for Use with High-tension Distributer. — A top view of a transformer spark-coil showing the beginning of the wires for connecting it to the other parts of the ignition system is shown in Fig. 184. This coil can be used for ignition in a single-cylinder motor with only one spark-plug, just as any unit coil would be used for the same purpose. But on account of its ability to do more work than is required for a motor with only one combustion chamber, it can be used to

transform current for ignition in several combustion chambers, each chamber having its own spark-plug. This requires a distributer for directing the high-tension current to the different spark-plugs, as is explained later. Any one-unit spark-coil can be used for ignition in several combustion chambers with a suitable distributer, provided the spark-coil is able to stand up under

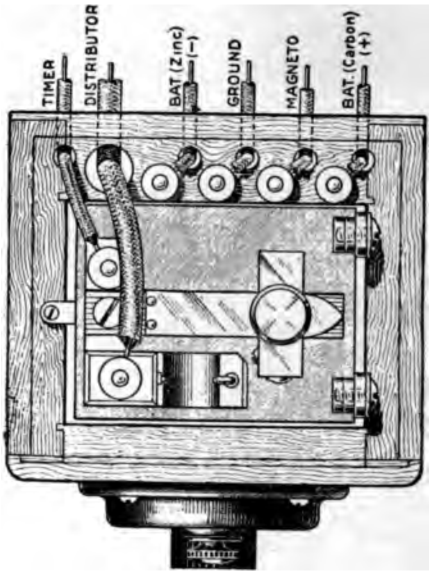


FIG. 184.

Trembler Spark-Coil for use with a High-tension Distributer to Direct Current to Several Spark-Plugs Consecutively. Autocoil Company.

the work. Heating and burning at the trembler contacts is one of the chief difficulties when a spark-coil is overloaded, as may be the case when an ordinary coil is used for ignition in several cylinders, as just mentioned.

147. Plain Transformer Spark-Coils without a Trembler. — Coils of this nature are used in connection with an interrupter which is entirely separate from them. The interrupter may be mechanically operated, as when it is a separate piece of apparatus or part of a magneto, or of a device for interrupting the low-tension current and distributing the high-tension cur-

rent, or it may be electrically operated, as when it is part of a master trembler-coil. Plain transformer coils have long been extensively used in motor-cycle ignition. Their use is becoming rapidly extended in other fields, especially that of the automobile.

A plain transformer spark-coil in a cylindrical case is shown in Fig. 185. It has two low-tension terminals and one high-tension terminal.

A double transformer spark-coil is shown in Fig. 186. Two separate coils are inclosed in the cylindrical case. There are

Fig. 185.

Non-trembler Transformer Spark-Coil in a Cylindrical Case.

five terminals, — three low-tension and two high-tension ones. One of the low-tension terminals is connected to both coils.

Fig. 187 is a single transformer coil inclosed in a wooden box, which also contains a condenser. There are four terminals.

Fig. 186.

Two Non-trembler Transformers Inclosed in Cylindrical Case.

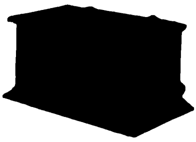


Fig. 187.

Non-trembler Transformer with Condenser and Terminal Connected to one side of the Condenser.

Two of the terminals are low-tension, one is high-tension, and the remaining one is for one side of the condenser. The other side of the condenser is connected to one of the low-tension terminals.

148. Connections to Trembler Spark-Coils. — Some makers of spark-coils mark the terminals of the coils to indicate which terminal is to be connected to the positive side of the battery,

etc., and recommend that the connections be made accordingly. One reason for this recommendation is that, when the connections are made as indicated, the wear on the contact-points of the interrupter (trembler contacts) is greater at the contact-point which is the easier to repair and the less expensive to replace with another. A second and less common reason is that better ignition is obtained when the ignition spark jumps in one direction than when it jumps in the opposite direction. When the battery connections are made as indicated on the coil, the ignition spark jumps in the direction which is the better for ignition.

CHAPTER XVI.

TIMERS AND SPARK-PLUGS FOR HIGH-TENSION IGNITION.

Timers.

149. Elementary Form of Timer. — The device which periodically closes the primary (low-tension) circuit of a jump-spark ignition system at the proper instant for ignition is called a timer when it is a separate and distinct piece of apparatus. It is not infrequently, but erroneously, called a commutator. A commutator, as it appears in an electric ignition system, is a part of a direct-current electric generator, or dynamo.

Probably the simplest form of timer is a shaft with a projecting lug or wire which strikes a stationary part as the shaft rotates, thus closing the electric circuit once each revolution of the timer shaft. A timer with only one stationary contact will operate only one spark-coil when used in the ordinary manner.

The rotor of the timer is the part, or parts, which rotate with the driving shaft. The casing, which is ordinarily referred to as being stationary, can be rocked around the shaft a quarter-revolution or less in order to advance or retard the spark; that is, to vary the instant of ignition relative to the position of the piston of the motor during the movement of the piston.

150. A roller-contact timer with four stationary contact-pieces, for operating four spark-coils, is shown in Fig. 188. It has a metal casing *A* into which fits an insulating ring *B*, generally of wood fiber. Four terminals *C*, *D*, *E*, *F*, for wires leading to the spark-coils, project radially from the casing. The terminal *C* connects with a contact-piece *G* whose contact surface is flush, or nearly so, with the inner surface of the insulating ring. The contact-piece and terminal are insulated from the metal casing. In the same manner, the terminal *D* has the contact-piece *H*, and the other two terminals have similar contact-pieces. The rotor *K*, with two arms, is rigidly fastened to a shaft which

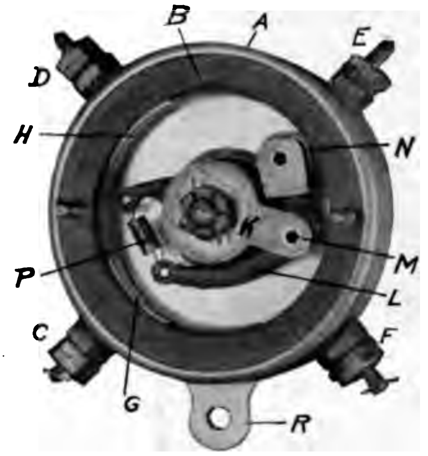


FIG. 188.
Timer for Four Spark-Coils. Roller Contact.

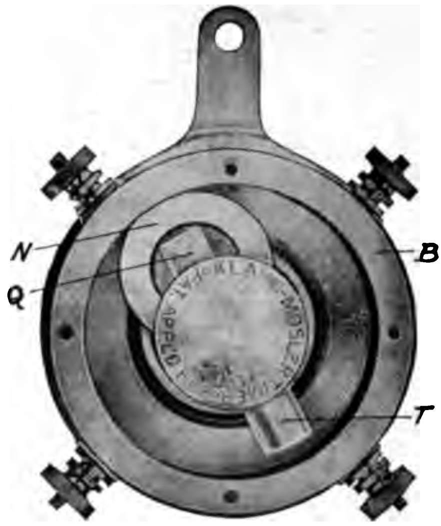


FIG. 189.
Rolling Contact Timer for Four Spark-Coils.

ends through and rotates in a hub that is part of the metal ing. The bent lever L is connected to the short end of the n K by pin M. A contact roller N is pinned to the short l of the bent lever. The contact roller is kept pressed against : insulating ring and stationary contact-pieces by means of a led tension spring P. This spring pulls the long end of the it lever toward the other rigid arm which projects to the left

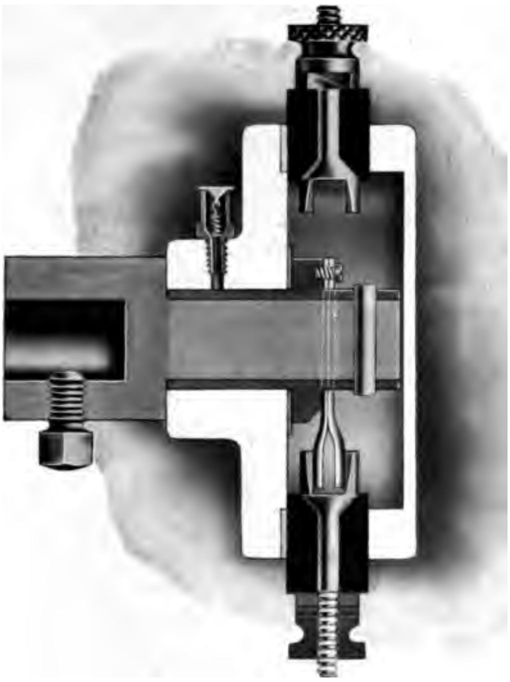


FIG. 190.
Timer with Rubbing, or Sliding, Contact. Sectional View. Pittsfield Spark Coil Company, Dalton, Massachusetts.

m K. All of the parts inside of the insulating ring rotate l together form the rotor of the timer. They are all electri-ly connected together.

ls the rotor revolves, the contact roller makes contact suc-sively with the contact-pieces of the terminals, thus com-ting the electric circuit between the shaft and each of the

terminals in regular order. The casing is prevented from rotating by means of a link or rod connected to the arm *R*. The arm *R* is frequently called the timing lever.

Another timer which has rolling contact is shown in Fig. 189. The contact roller *N* in this timer has the form of a ring and is mounted on a ball bearing whose balls run in a groove in the circular part of *Q*. The contact ring *N* is kept pressed against the inside surface of the insulating ring by means of a coiled compression spring inside of the part *T*.

151. A sliding-contact timer is illustrated in Fig. 190, which is a sectional view. The rotor contact-piece is a forked spring which passes between the fork-shaped ends of the stationary contact-pieces, thus making a rubbing, or sliding, contact. The stationary contact-pieces are insulated from the metal casing by cylindrical pieces of insulating material, one insulator for each contact-piece.

152. A timer with normal-pressure contact is shown in Fig. 191. Two views are given. The rotor of this timer consists only of a

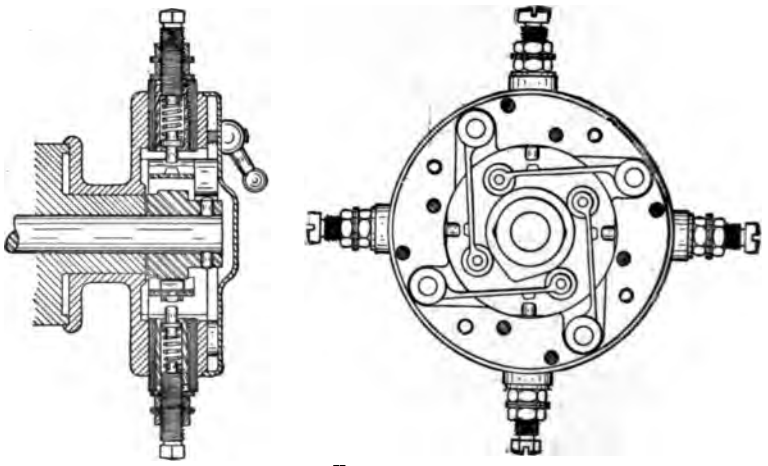


FIG. 191.
Timer with Plain Pressure Contact. For Four Spark-Coils.

cam whose lobe (protuberance) presses against the four small rollers successively and moves them outward as the rotor revolves. Each of the four small rollers is carried in the end of its own

spring, whose opposite end is rigidly fastened to the casing. Each roller spring carries a small contact-piece. When the roller is moved outward by the action of the cam-lobe, the contact-piece on the spring presses against the mating stationary contact-piece opposite it. The stationary contact-piece is pressed inward by a coiled compression spring which allows the contact-piece to move outward when the contact-pieces are pressed together.

Spark-Plugs.

153. General Description. — The ordinary form of high-tension spark-plug has the following essential parts: A hollow metal piece (bushing) threaded along part of its outside for screwing into the cylinder of the motor, and usually having a hexagonal head to be gripped by a wrench; an insulator of some such material as porcelain, steatite, mica, or molded compound which fits into the bush; and a central wire, rod, or spindle which passes through the insulation from end to end. One end of the spindle, or a piece of metal fastened to its end, is either brought near to the end of the threaded bushing or to a piece of metal that projects from the bushing, thus forming the spark-gap which goes inside of the combustion chamber of the motor. The outer end of the spindle is provided with a terminal to which the high-tension wire can be connected. Packing is used when necessary, to make the plug gas-tight.

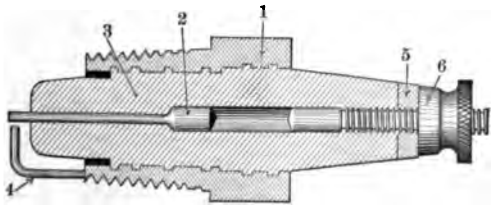


FIG. 192.
Spark-Plug with Insulation Molded into Place.

154. Single-gap Jump-spark Plugs. — A simple form of plug is shown in Fig. 192. The outer bushing 1 is insulated from the central spindle 2 by the insulator 3, which is molded into place.

A bent wire 4 projects from the bushing so that the end of the wire is near the point of the insulated spindle. The space between the ends of the spindle and of the bent wire is the spark-gap. The outer, threaded end of the central spindle has a ring-nut 5 and a thumb-nut 6 between which the connecting wire can be clamped. The spindle extends from end to end of the insulation, although this is not clearly shown in the illustration.

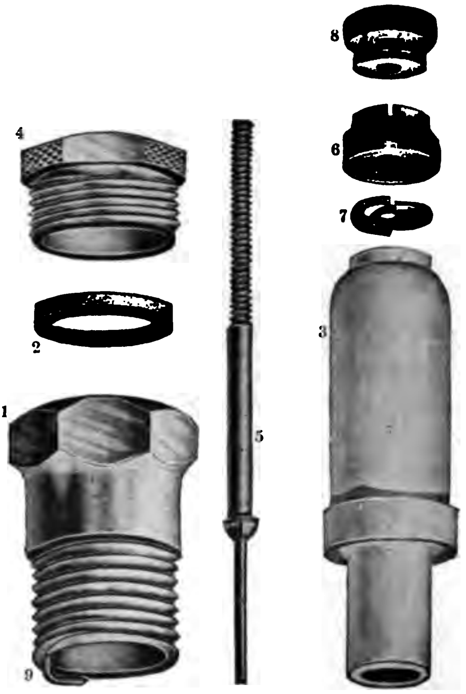


FIG. 193.
Parts of Spark-Plug with Separately Molded Insulation.

The parts of another spark-plug are shown separately in Fig. 193. The threaded outer bushing 1 has an interior shoulder against which the packing gasket 2 rests when in place. The porcelain insulator 3 enters the bushing from the top and is clamped down by the threaded gland 4 so that the shoulder at the under side of the ring on the porcelain presses against the gasket, thus making a gas-tight joint. The hole through the

porcelain is large at the bottom, but the greater portion of its length is small enough to fit the spindle 5 loosely. The spindle enters the porcelain from the bottom, so that the shoulder on it strikes the lower end of the small part of the hole in the porcelain. Packing, such as fiber asbestos, is interposed between these two shoulders. The spindle is drawn tightly into place by the ring-nut 6, under which is the spring washer 7, whose elasticity allows for variation in the expansion and contraction of the spindle

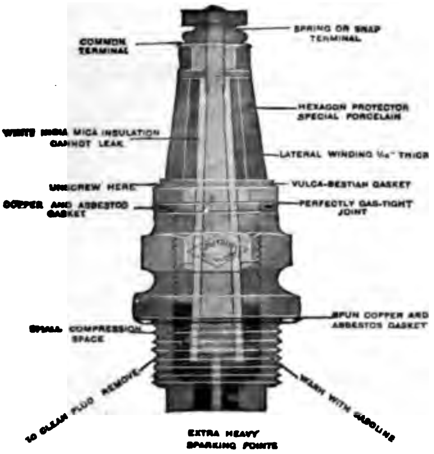


FIG. 194.
Spark-Plug with Sheet Mica Insulation and Porcelain Protector.

and the porcelain as they become heated and cool. The usual terminal thumb-nut 8 is provided. The bent wire 9 projects from the bushing so that its end comes within sparking distance of the spindle when the latter is in place. The large hole in the lower end of the porcelain, and the contracted outer diameter of the same end of the porcelain, give a long stretch of insulating surface between the spindle and bushing.

The spark-plug in Fig. 194 has mica insulation in the form of a sheet wrapped around the central spindle. A protective porcelain insulator is placed between the bushing and the terminal to which the outside wire can be connected. The body of the spindle is tapered where it comes into contact with the mica insu-

lation, thus making the spindle easily removable. The nut which holds the spindle in place clamps against the end of the porcelain protector.

155. Spark-Plugs with Two or More Spark-Gaps. — When the ignition current is supplied by a magneto, there is more apt to be burning away of the sparking points of the spark-plug than when an electric battery and a transformer spark-coil is used. In order to overcome the burning of the spark-points as far as possible, or at least to give the plug longer life, two or more pairs

Fig. 195.

Spark-Plug with Two Spark-Gaps. Full View and Part Sectional View.

of spark-points are used in one plug. The spark then passes sometimes between one pair of points, and sometimes between another pair, thus distributing the work and heat.

The spark-plug shown in Fig. 195 has two spark-gaps obtained by bringing two bent wires from the outer bushing to within sparking distance from the end of the central spindle. The ends of the wires are bent up so that if oil or water collects on them it will have a tendency to run down to the angle of the bend when the plug is in a vertical position, as shown. The sectional view shows how the plug is constructed. The insulation between the insulated central spindle and the outer bush that screws into the motor is of steatite coated with porcelain. The shoulder of

the insulator rests on a packing ring between it and the interior shoulder of the threaded bush. The insulator is held in place by a wedge-shaped ring which is forced into place and then held there by bending the top of the outer bush inward over it.

FIG. 196.

Spark-Plug with Four Spark-Gaps. J. S. Bretz Company, Times Building, New York City.

In the spark-plug shown in Fig. 196 the insulated central spindle has four prongs each of which is within sparking distance

FIG. 197.

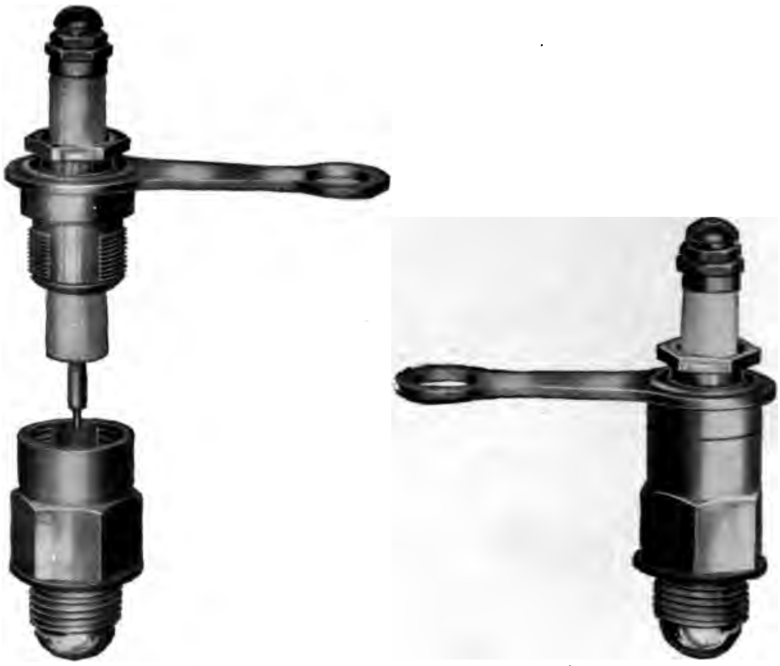
Eisemann Platinum Spiral Spark-Plug. Eisemann-Magneto Company, New York and Detroit.

from the outer bush, thus forming four spark-gaps at which the ignition spark may jump.

More than one spark-gap is obtained in a simple manner in the plug shown in Fig. 197. The end of the outer bush is bridged by a wire around which is wrapped a short piece of thin platinum wire. The end of the insulated central spindle is flattened. The

spark may jump between the end of the spindle and the nearest part of any of the turns of the platinum wire.

156. Separable Spark-Plugs. — Some spark-plugs are so constructed that they can readily be taken apart enough for cleaning without the use of any tool for taking them apart. The plugs shown in the next two illustrations are of this nature.



(*a*) (*b*)

FIG. 198.

"Breech Block" Separable Spark-Plug.

A separable spark-plug, Fig. 198, is shown "open" in view (*a*) for cleaning or examination. In view (*b*) the plug is "closed" ready for use. This plug differs from the ordinary type in having the bushing threaded to the remainder of the plug by a screw thread, part of which is cut away in the same manner as in the breech-block of a cannon. The thread on each part is cut away in three places, each extending about one-sixth of the way around the circumference. This leaves three sections of thread

of equal length on each part, the sections being at equal distances apart. The externally threaded part can be dropped into the bushing to almost the full distance that it is to enter, then a twist of less than one-sixth of a turn screws the parts firmly together. When the bushing has been screwed into the motor,

(a)

FIG. 199. (See also next page.)

"Detachable" Spark-Plug with Knife-edge Spark-Gap. Knapp-Greenwood Company, 1000 Boylston Street, Boston, Mass.

the detachable part of the plug can be quickly removed by twisting it through less than one-sixth of a turn (the flat handle is provided for doing this), then lifting the detachable part straight out. A wire is shown connected to the plug by means of a spring clip.

Another separable plug, Fig. 199, is shown "open" in (a) and "closed" at (b). The threaded bushing is slotted, a portion

of the slot being cut at an angle like a screw thread, to receive the smooth portion of the two screws that fasten the handle to the inner removable part of the plug. In putting the parts together, the detachable portion is dropped into the bushing and then given part of a turn. A portion of the smooth body of each of the two screws slides along the inclined edge of the

(b)
FIG. 199 — *Concluded.*

corresponding slot, thus forcing the parts tightly together. The parts can be separated by the reverse movement.

The spark-gap in this plug is the space between the edges of two hollow cylindrical parts. The lower one of these is fastened to the insulated central spindle by the nut at the lower end of the spindle. The spark may jump anywhere across this gap. The insulation is built up of mica disks.

157. The width of the spark-gap is ordinarily greater for an ignition system having a trembler transformer to which low-tension current is supplied by a battery, than in a system operating on current from a high-tension magneto. A satisfactory distance between the spark-points of an igniter when the high-

tension current comes from a trembler spark-coil is $\frac{1}{32}$ of an inch or slightly more. Sometimes as much as $\frac{3}{32}$ of an inch is recommended by the makers of spark-coils, but this is unusual. For current from a high-tension magneto, a distance from $\frac{1}{64}$ to $\frac{1}{50}$ of an inch between the spark-points appears to give the best satisfaction. It is of course possible to construct spark-coils and magnetos each of which will operate most efficiently with a width of spark-gap which is the same for all, but this condition has not yet arrived in general practice.

CHAPTER XVII.

JUMP-SPARK IGNITION SYSTEMS WITH MAGNETIC TREMBLER INTERRUPTERS AND INDIVIDUAL TRANSFORMERS.

158. Introductory. — While the ignition systems in this chapter are illustrated and described as operating on current from a battery, they can all be operated with equal satisfaction on current from a direct-current generator. They may also be operated on high-frequency current such as is produced by magnetos with more than two magnetic poles of the type intended for ignition usage, provided the trembler blade of the interrupter is light enough to vibrate at a very high rate.

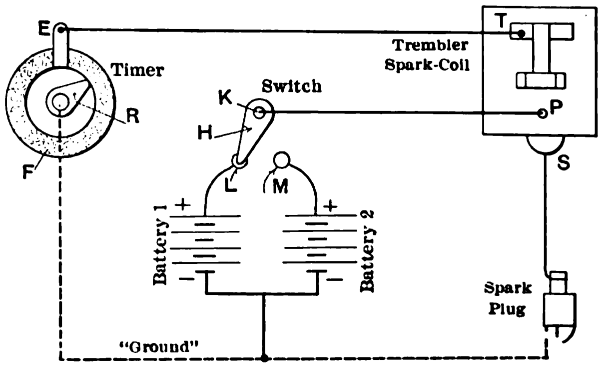


FIG. 200.
High-tension Ignition System with One Spark-Plug.

159. System with One Spark-Plug and Trembler Spark-Coil.— In Fig. 200 the spark-coil is shown with the trembler and the two low-tension terminals at the top, and the high-tension terminal S at the side of the box. The timer is represented conventionally by a ring F of insulating material. A metal contact-piece E is set into the insulating ring, and a rotor R makes electric

contact with the contact-piece E once during each revolution. The rotor of the timer is represented as electrically connected to the metal of the motor by the broken line marked "ground." Two batteries are shown, either of which can be thrown into circuit by means of the switch whose blade H can be swung around the pin K so as to make contact with either, or neither, of the two contact-points (switch-points) L and M.

When the rotor R of the timer closes the battery circuit by coming into contact with E during its rotation, current flows from the positive side of the battery 1 (as the switch is shown set) through the switch to the low-tension terminal P of the spark-coil, through the primary winding of the spark-coil to the low-tension terminal T, thence to the contact-piece E of the timer and on through the rotor R of the timer to ground, which takes it to the grounded end of the wire connected to the negative side of the battery. The current completes its circuit through this grounded wire and the battery in series.

The high-tension current flows from the high-tension terminal S of the spark-coil to the insulated spindle (or firing pin) of the spark-plug, jumps the spark-gap to ground, and then returns to the spark-coil through the battery and switch in series. Some of the high-tension current may return from ground to the battery through the timer, but the portion following this return circuit would be small under ordinary conditions.

The so-called ground connection through the metal of the machinery has such slight electric resistance under proper conditions that parts which are connected to ground can be considered as directly connected together.

The rotor of the timer is grounded more or less perfectly by the contact of the rotor shaft with the metal of the bearing in which the shaft rotates. Sometimes a brush which bears on the shaft or some other part of the rotor, and is connected to ground, is used to insure more perfect grounding of the rotor. If a timer with an insulated rotor is used, a wire must be connected to the rotor to carry the current to the proper point outside of the timer. This wire replaces the ground connection of the rotor as shown in the diagram.

160. Auxiliary Condenser in an Ignition System. — In order to insure the occurrence of an ignition spark even though the contacts of the trembler-interrupter should happen to stick together, as on account of burning and fusing, an auxiliary condenser is sometimes used. This auxiliary condenser also protects the contact-points of the timer.

An auxiliary condenser used for the above purpose is shown in the diagram, Fig. 201, which represents an ignition system

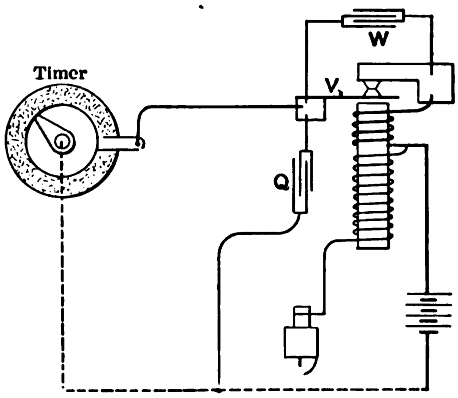


FIG. 201.
Auxiliary Condenser in Parallel with Timer is an Ignition System with One Spark-Plug.

that is the same as that in the preceding figure with an auxiliary condenser added to it. The condenser for protecting the contact-points of the trembler *V* is shown at *W* connected in parallel with the trembler contacts in the usual manner. The auxiliary condenser *Q* is connected in parallel with the timer, one side of the condenser being grounded. The action of the auxiliary condenser relative to the interruption of the current at the timer is similar to that of the usual condenser *W* relative to interruption of the current at the trembler contacts. The latter has been described. If the contacts of the trembler stick together, the interruption of the current, as the timer points separate from each other, produces, with the aid of the condenser, an ignition spark that is satisfactory for ignition. Without the auxiliary

condenser, the spark at the plug might be uncertain and weak. The spark when the trembler does not operate will be somewhat later than when it does, since the timer contacts naturally do not separate as soon as the trembler contacts when the trembler is operating properly. The auxiliary condenser may be either inside of the spark-coil box, or it may be separate in a box of its own.

It may be noted that if the auxiliary condenser is not connected to ground, or is otherwise disconnected, as by the breaking of the connecting wire or by error, the system will then be the same as one which never had an auxiliary condenser. No harm will be done, except very improbable injury to the timer contacts.

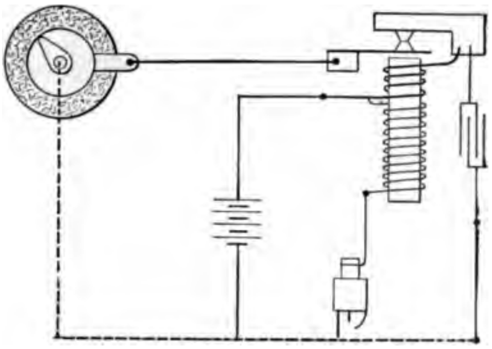


FIG. 202.

High-tension Ignition System with One Condenser in Parallel with Both the Timer and the Trembler Interrupter. One Spark-Plug.

161. Grounded Spark-coil Condenser. — A method of using only one condenser for both the trembler of the spark-coil and the timer is shown in Fig. 202. One side of the condenser is connected to one side of the spark-coil interrupter, and the other side of the condenser is grounded. This puts the condenser in parallel with both the trembler and the timer, the latter two being in series with each other. If the contact-points of the trembler separate while the circuit is closed at the timer, the condenser protects the trembler contacts and aids in the production of a good ignition spark in the usual manner. If the trembler contacts stick together, then the condenser operates in

relation to the timer when the contact-points of the latter separate, as it does relative to the trembler contacts when they separate during the proper action of the system.

While the operation of this system is entirely correct when all of the connections are properly made, there is a very serious objection to it for general application by those not familiar with it. This objection is due to the fact that most spark-coils for ignition purposes have only three terminals, the condenser having both of its connections to the other parts made inside of the coil box. But when the condenser is grounded, there must be a fourth terminal. The average operator will make connections to only three of these, trying them till they are so made that the trembler vibrates. This leaves the condenser out of action. The result is heavy sparking and rapid burning at the trembler contacts, together with unsatisfactory ignition sparks and correspondingly bad ignition. The trembler contacts may be burned away so as to stop operation, or stick together, in a few minutes. The same effects are produced if the connections are properly made at first, and the ground connection then becomes broken or loose, which is a thing that often happens with unskilled operators.

In the hands of a skilled and careful operator this system is entirely satisfactory, however.

162. Individual Trembler-coil System. — Fig. 203 represents a system with four trembler spark-coils and the same number of spark-plugs, a spark-coil for each igniter plug. This is applicable to a four-cylinder motor of the single-acting type, or to a two-cylinder motor of the double-acting type.

The timer in this case has four stationary contacts, *a*, *b*, *c*, *d*, spaced at equal distances around the insulating ring. Each of these contacts is connected to one of the low-tension terminals of a corresponding spark-coil. The spark-coils are lettered *A*, *B*, *C*, *D*, to correspond to the lettering of the stationary contacts, or terminals, of the timer. The remaining low-tension terminals of the spark-coils, one terminal on each coil, are connected to a main wire which leads to the battery switch.

When the rotor revolves counter-clockwise, the spark-coils

are caused to operate in the consecutive order *A*, *B*, *C*, *D*. The connections between the high-tension terminals of the spark-coils and the spark-plugs are made so that the sparks jump at the plugs in the consecutive order 1, 3, 4, 2, this order being one that is usual for four-cylinder motors of the automobile type. It is customary in such motors to ignite first in the front cylinder, second in one of the middle cylinders, third in the rear cylinder,

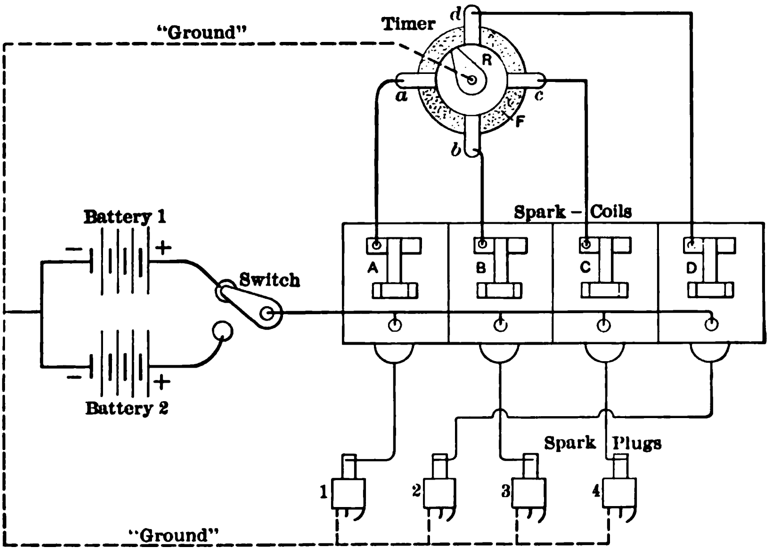


FIG. 203.

Multi-coil Ignition System with Four Spark-Plugs.

and fourth in the remaining middle cylinder. The numerical order of ignition might also be 1, 2, 4, 3, in accordance with this.

The timer has no condenser in parallel with its contact-points, consequently, if the trembler contacts of one of the spark-coils stick together, there will be no spark at the corresponding plug, and one of the cylinders will misfire.

163. Synchronized System with Master Trembler-Coil. — In Fig. 204 four transformer spark-coils without interrupters, or tremblers, are operated on battery current which passes through a master trembler-coil. The trembler of the master coil vibrates

so as to rapidly interrupt the current for each transformer during the time the circuit for that transformer is closed by the timer. The transformers have neither tremblers nor condensers. Each transformer is connected to its own spark-plug.

While the battery circuit is closed for battery 2 as shown, current flows from the positive side of the battery through the switch and winding of the master trembler-coil to the trembler

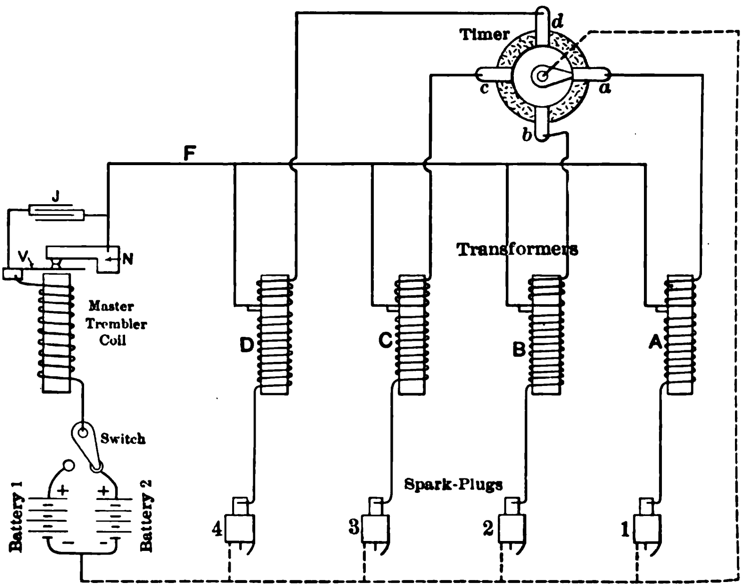


FIG. 204.

Synchronized High-tension Ignition System with Four Spark-Plugs.

V, through the contacts of the trembler to the stationary metal piece *N*, thence through the main wire *F* to the transformer *A* and through its primary winding to the contact-piece *a* of the timer, then through the rotor of the timer to ground, and from ground through the ground wire of the batteries to the negative side of the battery. The trembler of the master coil vibrates during this time, thus interrupting the current through the transformer so as to cause a series of sparks to jump between the spark-points of the spark-plug 1. The action is similar for each

of the other transformers as the rotor of the timer revolves and closes the circuit at the stationary contacts of the timer in regular order.

The condenser *J* is in parallel with the trembler of the master coil and acts in the same manner as when used in connection with a single transformer-coil. This elementary system has only the one condenser.

If the trembler contacts stick together or fail to make electric contact with each other, the whole ignition system fails to operate, or becomes dead, as a result, and the motor stops. The trembler contacts of a master coil used in this manner are more apt to burn so as to fail to make electric contact with each other, or to stick together on account of fusing, than the same trembler used in connection with one coil only. This greater liability to trouble is on account of the greater service the trembler is required to perform when used on a master coil. In this particular system, the service of the trembler is four times as great as for a single spark-coil, since there are four transformers for which the trembler must interrupt the current.

164. Synchronized System with Master Trembler-coil and Auxiliary Condensers. — This system, shown in Figs. 205 and 206, is the same as that of the preceding figure with four condensers, one for each transformer, added to it. There is also a key-switch *E* inserted in the circuit of each transformer — four key-switches in all, one for each transformer. Each switch is shown just above its transformer. Its blade is a flat spring, something like that of the trembler. The elastic action of the spring keeps the switch closed except when it is forced open by the pressure of the hand or finger of the operator on the button *K*. The purpose of these key-switches is to afford a means of cutting out the ignition from any one of the combustion chambers at will, as when testing to discover which cylinder is misfiring, when this trouble occurs. The switches do not in any way affect the operation of the system while the motor is running in the ordinary manner.

Each of the auxiliary condensers has one side grounded, all of them being grounded through one main wire. The condenser *Q*

has the other side connected to the stationary block *E* of the key-switch just above the transformer *A*. This is practically the same, so far as the operation of the condenser is concerned, as if the condenser were connected to the stationary contact *a* of the timer, since there is no transformer winding, or other inductive resistance, between the switch and timer. The con-

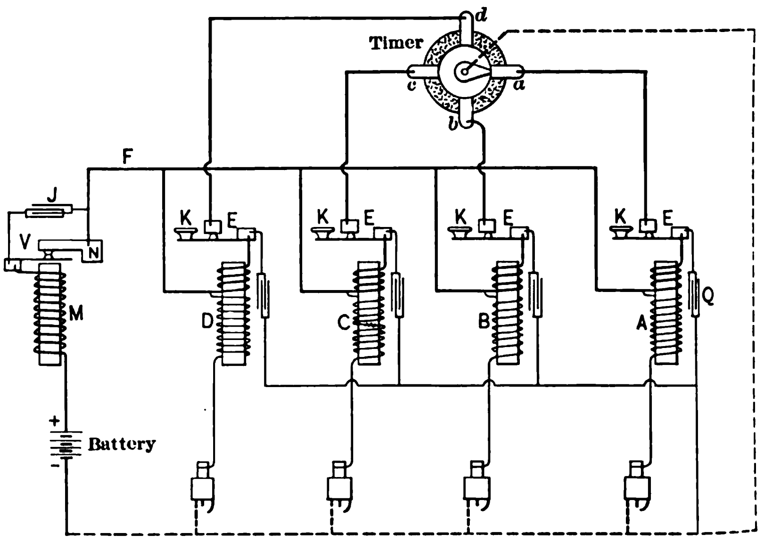


FIG. 205.
Synchronized Ignition System with a Grounded Condenser in Parallel with Each Transformer Spark-Coil.

denser *Q* is therefore in parallel with the timer. The other three auxiliary condensers are similarly connected relative to the transformers *B*, *C*, and *D* respectively.

If the trembler contacts (of the master coil *M*) stick together so that the trembler does not interrupt the current, then the auxiliary condensers will act so that when the timer circuit is broken by the separation of the timer rotor from any one of its stationary contacts, a spark suitable for ignition will jump between the points of the corresponding spark-plug. This would probably not occur if there were no auxiliary condenser, or if a spark did jump it would not be as strong as when there is a condenser in

parallel with the timer. The condenser also protects the contact-points of the timer, which would suffer during the time the

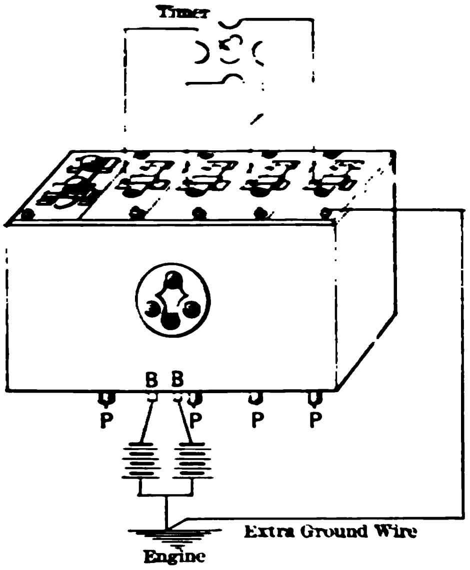


FIG. 206.

Constructive Form of Fig. 205. C. F. Splitdorf, New York City.

trembler contacts are stuck together, if the auxiliary condensers were not in the system.

165. Ammeter and Voltmeter Permanently in the Circuit of a High-tension Ignition System. — Fig. 207. The ammeter and voltmeter are mounted on the same base, and the upper terminal (marked —) is in connection with both instruments. The voltmeter terminal (marked +) is at the right-hand side, and the ammeter terminal at the left-hand side.

The upper terminal, common to both the ammeter and voltmeter, is connected to the negative side of the battery. The ammeter terminal is connected to the metal of the motor. The path of the battery current is from the positive side of the battery to and through the primary of the spark-coil which is operating at the instant, then to the timer and through it to ground, which brings the current to the engine metal, thence to and through

the ammeter to the common terminal (−) of the combined instruments, and then through the connecting wire to the negative terminal of the battery.

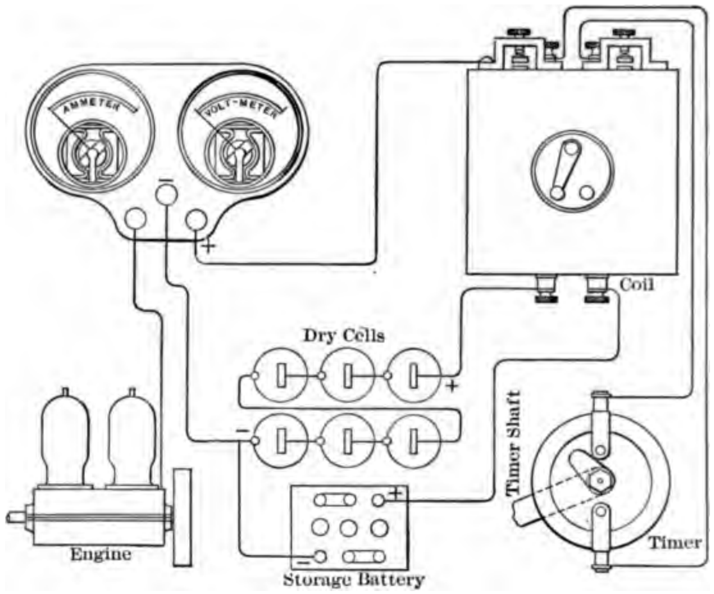


Fig. 207.
High-tension Ignition System with an Ammeter and a Voltmeter Permanently in Circuit.

The connections between the voltmeter and the battery must not include the timer, an interrupter, or the winding of a coil. The connection to the negative side of the battery shows plainly that it meets this condition. The positive (+) terminal of the voltmeter is shown connected by a wire to the contact-block of one of the spark-coils. In order for this connection to be correct, both of the contact-blocks of the spark-coils must be electrically connected together by a non-inductive conductor of low resistance. There must also be non-inductive, low-resistance connection between the contact-blocks and the terminals at the bottom of the spark-coil when the switch is closed. The voltmeter will not give the voltage of the battery if this connection includes the winding of the spark-coil, as is true in many makes of coils.

If the connections of the coil are not known, a suitable place for connecting the wire from the (+) terminal of the voltmeter can generally be found in the following manner:

Disconnect one battery wire from the spark-coil;

Connect the wire from the (+) terminal of the voltmeter to the spark-coil terminal to which the battery wire is still attached;

Read the voltmeter while the motor is running;

Disconnect the voltmeter wire from the spark-coil and connect it to other parts of the spark-coil (except the high-tension terminal) till a place is found which gives the same voltage reading as was obtained before, the motor still running;

Connect the other battery wire to the spark-coil, throw the switch over to its other position, and test out for the second battery as before, omitting the battery-wire terminal to which the first battery wire is connected at the spark-coil.

If the same point on the spark-coil answers for reading the voltage of both batteries, then it is a suitable place for connecting the wire from the (+) terminal of the voltmeter.

166. Speed of the Timer. — When a timer is of the general nature of those described in this chapter, its speed of rotation is as follows:

Half as fast as the crank-shaft of four-cycle motors, which is the same speed as that of the cam-shaft.

The same as that of the crank-shaft of two-cycle motors.

CHAPTER XVIII.

HIGH-TENSION DISTRIBUTER SYSTEMS WITH BATTERY CURRENT.

167. General. — In systems of this nature only one transformer spark-coil is used, and the high-tension current from it is distributed to the spark-plugs, generally to one plug at a time. A spark-coil with a magnetic interrupter of the trembler type is used in connection with a slightly modified form of the ordinary timer in some systems. In other systems the spark-coil is of the plain transformer type (without interrupter) used in connection with a mechanically operated contact-maker which closes and breaks the battery circuit at the proper instant for ignition.

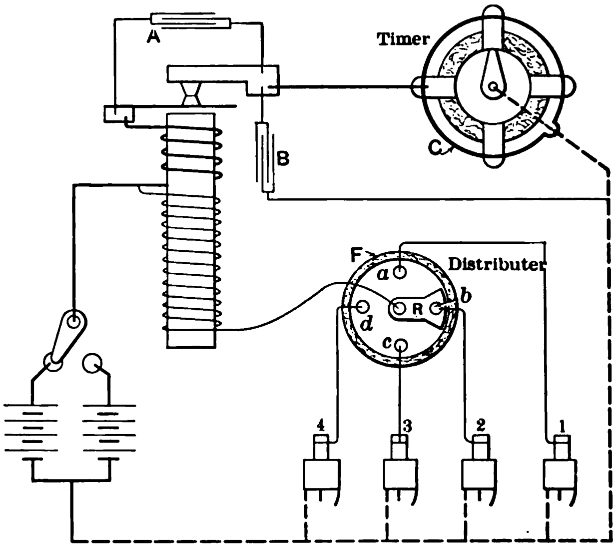


FIG. 208.
High-tension Distributer Ignition System with Trembler Spark-Coil.

168. High-tension Distributer System with Trembler Spark-Coil. — In Fig. 208 one low-tension terminal of an ordinary

trembler spark-coil is connected to all of the four stationary contact-pieces of an ordinary timer. This connection is made by a wire leading from the transformer to one of the stationary contacts of the timer, together with a wire *C*, shown as a circle, which connects all of the stationary contacts of the timer together electrically. By this means the timer closes the battery circuit four times through the same transformer (the only one used) during one revolution of the rotor of the timer.

The distributer of the high-tension current is represented as a circular piece of insulating material *F* inside of which an insulated rotor *R* revolves and makes contact successively with four insulated contact-pieces *a*, *b*, *c*, *d*. The high-tension terminal of the spark-coil is connected to the rotor of the distributer. Each of the contact-pieces *a*, *b*, *c*, *d* is connected to a corresponding spark-plug. The high-tension current is thus distributed to the spark-plugs, one at a time, in regular order.

The timer and distributer rotors revolve at the same speed when the timer has four stationary contact-pieces as shown. Both rotors are generally mounted on the same shaft. The rotor of the distributer is brought into contact with one of the stationary contacts to which the spark-plugs are connected, each time the circuit is closed by the timer. If the timer had only two stationary contacts, located diametrically opposite each other, then the timer would have to rotate twice as fast as the distributer. And if the timer had only one stationary contact-piece, its rotor would have to revolve four times as fast as that of the distributer.

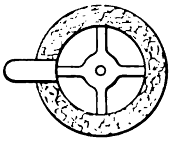


FIG. 209. Timer for High-tension Distributer System with Four Spark-Plugs.

A timer with only one stationary contact-piece, but with four contact-points on the rotor, is shown in Fig. 209. The rotative speed of this four-pointed rotor is the same as that of the distributer rotor when there are four spark-plugs.

The condenser *A*, Fig. 208, is in parallel with the magnetically operated interrupter of the spark-coil in the usual manner. Condenser *B* is in parallel with the timer, so that ignition will continue even though the contact-points of the magnetic interrupter

on the spark-coil stick together so as not to break the circuit. This feature has been described in connection with other systems.

169. Mechanically Operated Contact-Maker and High-tension Distributer System with Battery Current. — Fig. 210. The mechanical contact-maker which replaces the timer of the preceding system is represented by a stationary insulated piece *H* which has a contact-point *F*, and by a rocker which is rocked

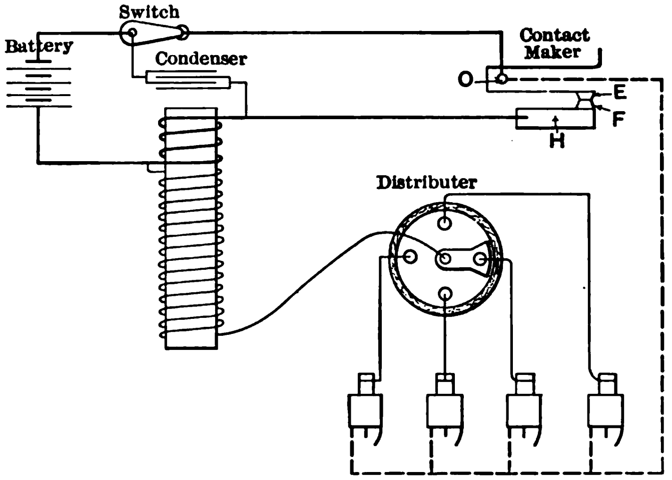


FIG. 210.
High-tension Distributer System with Mechanically Operated Contact-Maker.

on the pin *O* by mechanical means. The movable contact-point *E* of the rocker is thus brought into contact with and separated from the stationary contact-point when an ignition spark is to be produced. This form of contact-maker is fully described in connection with the following illustrations.

The spark-coil is of the plain transformer type (without interrupter). The condenser is part of the spark-coil and is in parallel with the contact-maker. The distributer is of the usual form that has been described in connection with other systems. The contact-maker must close and break the battery circuit four times during each revolution of the distributer for the four spark-plugs shown. If the system were modified to operate six spark-plugs, then the contact-maker would have to make and

break the battery circuit six times during one revolution of the distributer, and similarly for whatever number of spark-plugs are used. The distributer must have as many stationary contacts as there are spark-plugs to be operated by it. The rotor of the distributer may be mounted on the shaft that operates the contact-maker, in order to obtain a compact form. This is the more usual construction.

170. Unisparker. — The constructive form of the contact-maker, some of whose parts are shown in connection with the preceding ignition system, is illustrated in Fig. 211. The driving

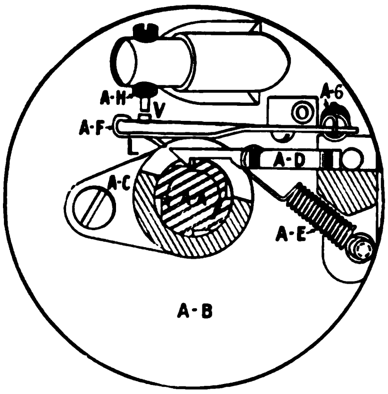


FIG. 211.
Contact-Maker of Unisparker.

shaft A-A rotates counter-clockwise, as indicated by the arrow. It has four notches to correspond to the same number of spark-plugs to be operated. As the shaft A-A rotates, each of its notches in turn catches the hook at the end of the snapper A-D and draws the snapper forward against the resistance of the coiled tension spring A-E, until the pressure of the cylindrical surface of the shaft against the snapper disengages the hook from the notch. The position of these parts at the instant of disengagement is shown in Fig. 212. The snapper then snaps back, and while doing so the point of its hook rides on the cylindrical surface of the shaft. This action presses the snapper against the lip L on the contact arm A-F and causes the latter, together with the contact-point V, to rock on the pin O so as to press the contact-point V

against the point of the stationary contact screw *A-H*. Contact-point *V* is mounted on a flat spring. When the snapper has moved to the position shown in Fig. 213, it passes out of contact with the lip *L*, and the contact-points are then rapidly separated by the action of the coiled spring *A-G*, which acts on the rocker arm *A-F* in such a manner as to rock it in the direction to separate the contact-points. Pressing the contact-

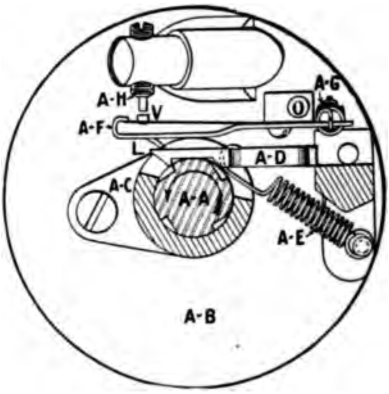


FIG. 212.
Unisparker Contact-Maker in Position just before making Contact.

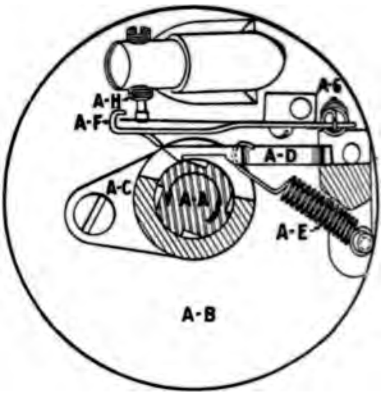


FIG. 213.
Contact-Maker with Contact-Points Pressed Together.

points *V* and *A-H* together closes the battery circuit. The duration of the time of contact is regulated by adjusting the insulated contact-screw *A-H* in the stationary part which holds it.

The snapper *A-D* is of very light weight, and the spring *A-E* is of sufficient strength to draw the snapper back with great rapidity. This movement is sufficiently rapid to give the same duration of contact between the points *V* and *A-H* whatever the speed of rotation of the shaft *A-A* up to speeds as high as are necessary for ignition. The primary circuit must of course be kept closed long enough to allow the battery current to reach a strength that will produce a spark at the spark-plug when the circuit is broken by the action of the contact-maker. If the adjustment is such as to make the period of contact longer than this, a stronger, or hotter, spark is produced at the igniter. The strength of the ignition spark can therefore be regulated by adjusting the con-

tact screw *A-H*. Only one ignition spark is produced for each ignition.

An external view of the unisparker is shown in Fig. 214. The contact-maker is in the lower part of the casing, and the upper part contains the high-tension distributer. Five wires connect to the latter at the top of the casing. One of these is at the center of the top for bringing high-tension current from the transformer. The other four are for carrying current to the spark-plugs. The terminals for the latter four wires are in a circle at equal distances from each other. The arm projecting toward the left just beneath the casing is the timing lever for advancing and retarding the spark. The rotating parts are driven by the shaft that projects from the bottom of the casing.

FIG. 214. (*See also* Figs. 211, 212, 213 and 215.)
Unisparker. Atwater Kent Manufacturing Works, Philadelphia, Pa.

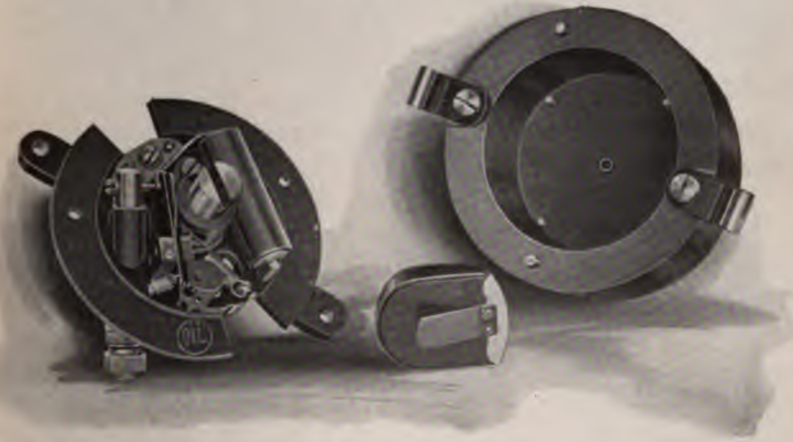


FIG. 215.
Parts of Fig. 214.

The interior construction is shown in Fig. 215. The com-

bined cover and distributer plate is at the right-hand side of the illustration, and the distributer rotor in the center. The contact-maker, at the left-hand side of the illustration, has a condenser enclosed in the cylinder which can be seen to the right of the driving shaft.

The coil box and switch to be used in connection with the combined contact-maker and distributer shown in the last two

FIG. 216.
Non-trembler Transformer Spark-Coil and Switch for use with Unisparker.

illustrations is seen in Fig. 216. No condenser is required in the coil box when there is one in the unisparker, as shown in the preceding illustration.

171. Combined Contact-Maker, Spark-Coil, and Distributer.—Fig. 217. A contact-maker of the kind just described, a transformer spark-coil (without a trembler), a condenser, a high-tension distributer, and a switch are all grouped together in this device. The contact-maker is inside of the small cover *A* at the top of the box. *B* is a starting button for starting the motor on spark, provided the cylinder of the motor contain combustible mixture. *C* is a wing-nut for holding the cover on the contact-maker.

The distributer *D* is in the form of a shaft with four winglike blades, of which one is lettered *E*. The high-tension current is brought to the distributer through the brush-holder *F*, which holds a brush (carbon pencil) that is forced outward by a spring

so as to make contact with the shaft of the distributer. *G* is the distributer board which carries four high-tension binding posts (terminals), each lettered *H*, for making connection to the wires leading to the spark-plugs. Each of the distributer blades *E* passes near to, or makes light contact with the inner end of the corresponding terminal *H*. Four push-buttons, each lettered *I*, are provided for cutting off the ignition from the correspond-

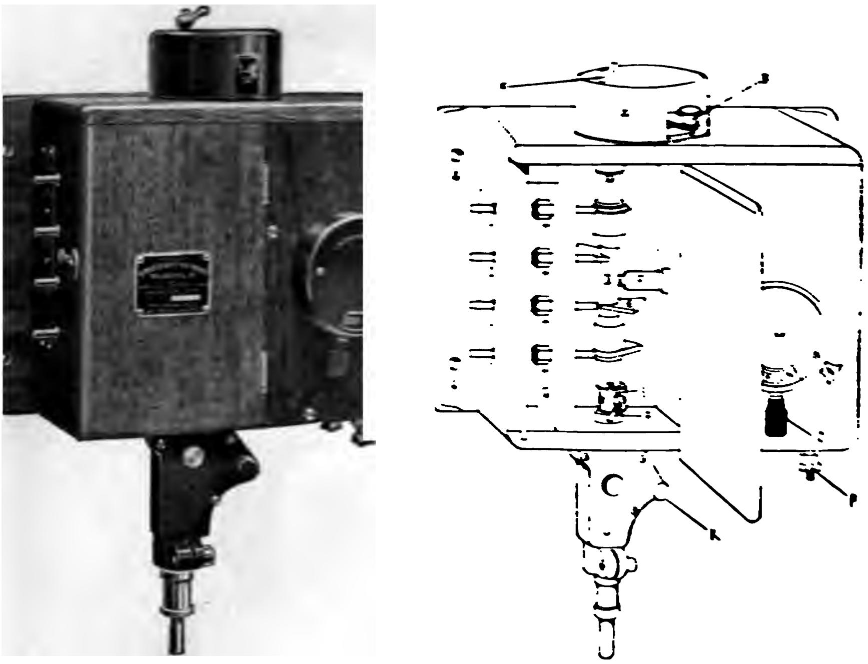


FIG. 217.
Atwater Kent Combined Contact-Maker, Spark-Coil and High-tension Distributer for Four Spark-Plugs.

ing cylinders of the motor. The housing *J* contains a spiral sleeve which drives the rotors of the contact-maker and distributer. This sleeve is moved by the operator by means of the spark-control lever at his hand, so as to advance or retard the spark. *M* is the switch, *N* the switch plug, and *O* the switch handle. The binding post for connecting to the positive (carbon) side of the battery is shown at *P*. The holes *Q* are for

screws or bolts to fasten the device in place. *R* is an oil tube. *S* is a clamping collar for setting the shaft *D* so as to have the spark occur at the correct instant.

172. Comparison of Unisparker and Ordinary Timer. — The contact-maker described in this chapter is decidedly more economical of electricity, and therefore of batteries, than a timer of the ordinary type. The ordinary timer must keep the battery circuit closed long enough, at the highest speed of the motor, to allow the primary current to become strong enough to produce a sufficiently large ignition spark when the current is interrupted; or, the timer must keep the circuit closed long enough for the magnetic trembler of the spark-coil to interrupt the current. If the motor is slowed down to half speed, then two or more ignition sparks will be produced by a trembler interrupter for each ignition, or if there is no trembler interrupter the current will flow twice as long, and at least twice as much electricity will be used for the corresponding one ignition as is necessary. A similar statement is true relative to still slower speeds of the motor. The electricity used for producing ignition sparks after the first one for one ignition is wasted. The same is true of current that flows after the current has become strong enough, when there is no magnetic interrupter of the trembler type. This waste represents the difference between the amount of electricity that is used by the contact-maker that has been described, and the ordinary form of timer.

CHAPTER XIX.

SPARK-PLUGS IN SERIES, AND IN SERIES-SHUNT.

173. Two jump-spark igniters can be operated in series with each other on current from the same spark-coil. An ignition system of this nature is shown in Fig. 218 with a trembler spark-coil. The spark-coil of necessity has four terminals, — two high-tension and two low-tension. The primary and secondary terminals of the coil are not connected together. The timer

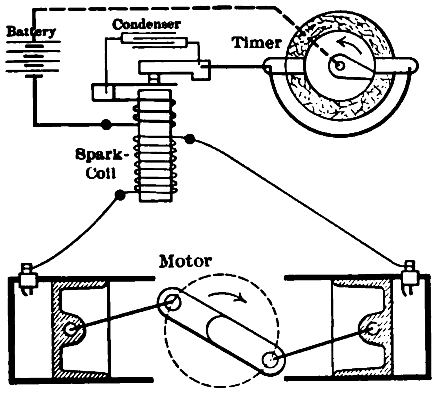


FIG. 218.

Two Spark-Plugs in Series with Each Other in a High-tension Ignition System.

has two stationary contact-pieces, diametrically opposite each other. These contact-points are connected together by a wire so that the timer closes the battery circuit twice each revolution at equal intervals. The spark-plugs are represented as in place in a motor of the four-cycle two-cylinder opposed type. The outer bushing of the spark-plug is grounded by its contact with the metal of the motor in the ordinary manner, so that these bushings are electrically connected together. The plugs are of the ordinary jump-spark type.

When the battery circuit is closed by the timer, the high-tension current flows from one of the terminals of the spark-coil to the insulated spindle of one of the spark-plugs, jumps the spark-gap of the plug to the outer bushing of the plug and the metal of the motor, then flows through the metal of the motor to the outer bushing of the other spark-plug, jumps the spark-gap to the insulated spindle of that plug, and then flows back to the spark-coil. A spark jumps at the same instant at both plugs. The sparks pass twice as often as necessary at each plug, since the ignitions occur alternately in the two cylinders.

The timer with the two stationary contacts rotates at half the speed of the crank-shaft (at the same speed as the cam-shaft) for a four-cycle motor. A timer with only one stationary contact-piece and one arm on the rotor can be used if it is rotated at the same speed as the crank-shaft.

This system has a feature relative to backfiring into the intake that does not appear in other systems. If the motor is rotated at very slow speed, as when starting it, and the ignition is very much retarded (set very late), then the mixture in both cylinders may be ignited at the same instant. Thus, suppose the crank-shaft and pistons are in the positions shown in the figure when the sparks jump, and the speed of rotation is slow. One piston is on its impulse stroke, and the other on its suction stroke. The one on the suction stroke may have drawn in combustible mixture enough to be ignited, and, since the inlet valve of that cylinder is open to admit the mixture, the flame will run back into the inlet passage, thus backfiring the incoming charge. This action occurs frequently in small motors that are cranked by hand when this system of ignition is used. Backfiring of course occurs in motors that do not have this kind of an ignition system, on account of entirely other causes. These other causes will cause backfiring in the series-plug ignition system, as well as in the other systems of ignition.

174. Series-shunt Connection of Spark-Plugs. — A diagrammatic representation of a high-tension ignition system in which current is supplied by one transformer to the two spark-plugs for two combustion chambers, one plug for each combustion

chamber, and which is provided with a short-circuiter for shunting the current from the spark-plug at which no spark is desired at the moment of ignition in the combustion chamber that contains a compressed charge, is shown in Fig. 219.

The transformer is of the non-trembler type with the primary and secondary windings not connected to each other. Low-

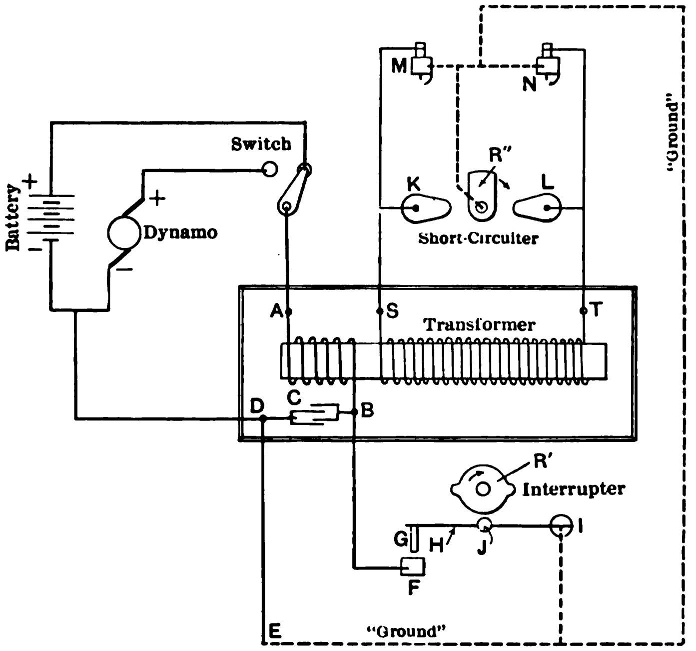


FIG. 219. (*See also* Figs. 220 and 221.)

Series-shunt Connection of Two Spark-Plugs in a High-tension Ignition System.

tension current is supplied either by a battery or by a dynamo, either of which can be thrown into the circuit by means of the two-point switch whose blade is connected to the terminal *A* of the primary winding of the transformer. The other low-tension terminal *B* of the transformer is connected to one side of the condenser *C*. The opposite side of the condenser is connected to the battery and dynamo, and is also grounded by the wire

DE which is connected to the metal of the engine at *E*. The primary terminal *B* is also connected to the insulated stationary contact *F* of the mechanically operated interrupter. The movable contact *G* of the interrupter is attached to a spring-blade *H* which is held in place by the grounded piece *I*. A piece of insulating material *J* is fastened to the spring-blade so that the lobes, or projections, of the rotor R' will strike it as the rotor revolves. The spring is pressed down by the lobe of the rotor so as to bring the contact-points together and close the primary circuit. The circuit is immediately broken as the lobe passes out of contact with the insulation *J*. It can be seen that the connections are such that the primary circuit cannot be closed by the interrupter unless the ground wire *DE* from the condenser is in place. It is therefore impossible to operate the system while the condenser is not connected into it so as to protect the contact-points of the interrupter, as well as to add to the effectiveness of the operation.

The novel feature of this system lies in the short-circuiting, or shunting, device connected into the high-tension circuit. This device resembles, in a general way, a high-tension distributer, but acts in the reverse manner. The short-circuiter cuts off the current from the spark-plug at which no spark is desired at the instant of ignition at the other plug, instead of directing current to the plug at which ignition is to occur, the latter being the method of the ordinary high-tension distributer.

The spark-plugs *M* and *N* are connected in series with each other to the secondary terminals *S* and *T* of the transformer. The insulated contact-piece *K* of the short-circuiter is also connected to the high-tension terminal *S* of the transformer. Likewise the other insulated contact-piece *L* of the short-circuiter is connected to the high-tension terminal *T* of the transformer. The grounded rotor R'' of the short-circuiter makes contact alternately with *L* and *K* during its rotation. The two rotors, R' and R'', of the interrupter and short-circuiter respectively, rotate at the same speed. They are ordinarily mounted on the same shaft as one piece of apparatus, although shown separately for clearness in the diagram.

When the rotors have revolved somewhat less than a quarter-revolution from the positions shown, the short-circuiter rotor makes contact with the grounded contact-piece *L*. These two parts remain in contact while, during further rotation of the rotors, the primary circuit is made and broken at the interrupter. The induced high-tension current passes, assuming a direction of flow, from the terminal *S* to the insulated spindle of the spark-plug *M*, jumps the spark-gap in *M*, thus reaching the metal of the engine, through which it flows to the grounded rotor R'' of the short-circuiter, thence to the contact-piece *L*, since R'' and *L* are in contact with each other, and on to the other high-tension terminal *T* of the transformer. No current flows through the spark-plug *N* during this operation, since the resistance of its spark-gap is enormous in comparison with that of the parallel circuit through the short-circuiter. The action is similar for producing a spark at the spark-plug *N* when the rotors have revolved a half-revolution farther. An ignition spark is thus produced first at one spark-plug and then the other, as required.

175. Constructive Form of Series-shunt Spark-plug Ignition System. — Fig. 220. This shows more clearly the nature of the apparatus used in the system illustrated diagrammatically in the preceding figure. Corresponding parts are designated by the same letters in the two figures, as far as possible. In Fig. 220 the rotor *R* is a combination of the two rotors R' and R'' of the preceding figure. *P* and *Q* are merely suitable terminals by means of which the high-tension wires are connected to the insulated terminals *K* and *L* of the short-circuiter. The short-circuiting pin which is a part of *R* corresponds to the rotor arm R'' of the diagram. The switch used is of the snap type, which eliminates the possibility of drawing an injurious arc in the switch when changing connections, as when switching from the dynamo to the battery, and vice versa.

The stationary contact-piece *F* of the interrupter is cup-shaped, and threaded on the inside so as to be adjustable. This piece, together with the part into which it screws, is insulated. The cup in the stationary contact-piece can be filled with oil, in which the breaking of the circuit will occur for each ignition. The oil

protects the contact-points against burning and fusing. The short-circuiter contacts *K* and *L* are mounted on insulating fiber pieces which are clamped into the stationary frame of the

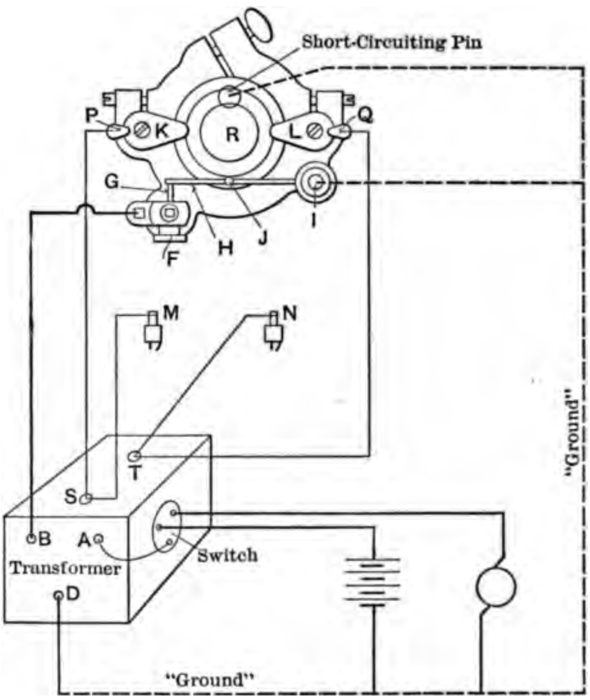


FIG. 220. (*See also* Figs. 219 and 221.)

Constructive Form of Series-shunt Spark-plug Ignition System. The Bruce-Macbeth Engine Company, Cleveland, Ohio.

combined interrupter and circuit-breaker. This frame is adjustable rotatively, and is clamped in position by means of the thumbscrew shown at the top.

The combined interrupter and short-circuiter is shown more in detail in Fig. 221.

The above apparatus is intended for use on a stationary engine. The spark-coil used is much larger than those customarily used for small motors, such as those of motor boats and automobiles.

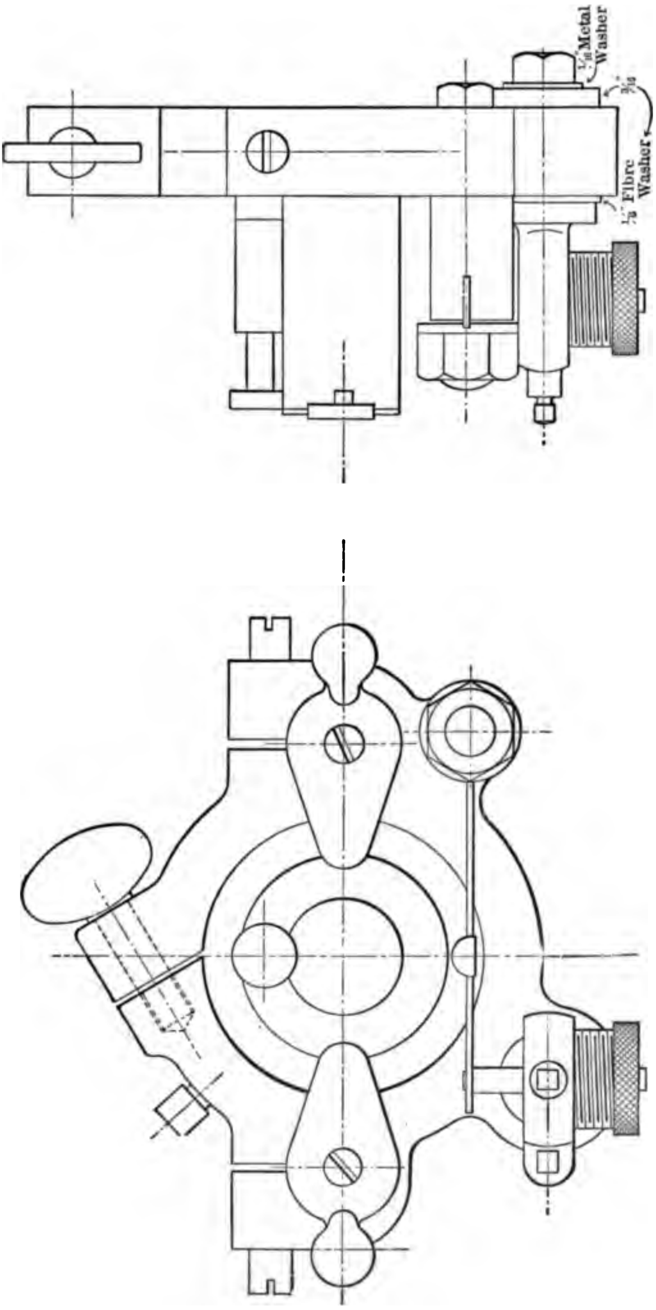


FIG. 221. (*See also* Figs. 219 and 220.)
Details of High-tension Short-Circuiter.

CHAPTER XX.

INTERRUPTER MAGNETOS AND JUMP-SPARK IGNITION SYSTEMS WITH MAGNETO CURRENT ONLY.

176. Introductory. — This chapter is intended to describe the more distinctive types of magnetos that are equipped with interrupters for making and breaking the primary circuit, or some part of it, at the instant a jump-spark is desired for ignition, and with a high-tension distributer for directing the secondary current to the spark-plugs in consecutive order. Some simple jump-spark ignition systems using magneto current only are presented in order to make clear the operation of the magneto. A rotative armature of the shuttle-wound type is used most frequently in the ignition-system diagrams, but this is merely a matter of convenience. Alternating-current magnetos with other types of armatures could be used equally well.

Magnetos which are especially designed to operate in connection with batteries in combination, or dual ignition systems, are not described in this chapter, but are described later in connection with their ignition systems.

177. Interrupted Primary Current Magneto Ignition System. — Fig. 222. The magneto has a single-wound armature of the shuttle type, which rotates between the pole-pieces of the magnets in the usual manner. One end of the armature winding is " grounded " by connection to the core of the armature. The other end of this winding is connected to a transformer spark-coil at the junction of the primary and secondary windings. This connection is made through a suitable brush (not shown) which has rubbing contact with the insulated part that rotates with the armature and to which the insulated end of the armature winding is electrically connected. The low-tension terminal of the primary winding *P* of the transformer spark-coil is connected to an insulated contact block *B* of a mechanically

operated interrupter. The interrupter is part of the magneto, although shown separate from it for convenience. The movable contact-point of the interrupter is fastened to the interrupter arm, or lever M, which keeps the contact-points pressed together except when the arm is lifted by the two-lobed cam C as the cam rotates. This cam is mounted on the armature shaft and rotates with the armature. The left-hand end of the interrupter

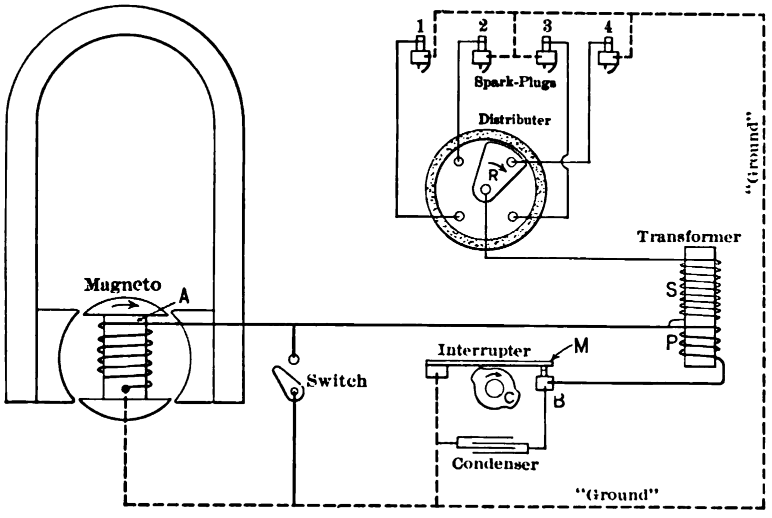


FIG. 222.

Jump-spark Ignition System with a Low-tension Magneto, a High-tension Distributer, a Separate Transformer and a Mechanical Interrupter for Breaking the Magneto-Transformer Circuit.

arm is fastened to a block which has ground connection with the body of the magneto. A condenser is in parallel with the interrupter.

The cam C is set in such a position relative to the armature of the magneto that the interrupter breaks the primary circuit while the armature is passing through the position which corresponds more or less nearly to the maximum flow of current through the armature winding and the primary winding of the spark-coil. The primary circuit is kept closed at the interrupter during a quarter-revolution or so of the armature preceding the

interruption of the current, during which quarter-revolution the current gradually increases from nothing to its maximum value. The maximum value of the current occurs when the armature has rotated slightly past the position shown; also when it has rotated slightly more than half a revolution past the position shown.

The interruption of the current that flows through the armature and the primary of the transformer spark-coil induces a high-tension current momentarily in the secondary winding *S* of the transformer. The high-tension terminal of the transformer is connected to the insulated rotor *R* of a distributer which directs the current to the spark-plugs in regular order as required. The high-tension current, after jumping the spark-gap at the plug, passes through ground to the metal of the magneto, thence to and through the magneto winding to the junction end of the secondary of the transformer. It is possible that at least some of the high-tension current passes through the interrupter by jumping across the opening between the contact-points while they are separated to break the primary circuit. The distributer is part of the magneto. The rotor of the distributer is generally driven by gears, one on the armature shaft and the other on the shaft that carries the rotor of the distributer. For four spark-plugs, each in its own combustion chamber, the distributer rotor revolves at half the speed of the magneto armature. The gear on the distributer shaft therefore has twice as many teeth as its mate on the armature shaft. The rotative speed of the armature shaft must be the same as that of the crank-shaft of a four-cycle motor that has four combustion chambers. For a four-cycle motor that has six combustion chambers, the rotative speed of the magneto armature must be one and a half times that of the motor crank-shaft.

The ignition can be cut out by closing the switch, which is shown open. Closing this switch short-circuits the armature of the magneto and thus practically leaves the spark-coil out of the circuit. Very little of the armature current then passes through the spark-coil, since the resistance of its primary winding is much greater than that of the short circuit through the

closed switch. The resistance of the primary of the spark-coil is both ohmic and inductive.

A safety spark-gap is generally provided in the secondary circuit to prevent overstraining of the insulation of the high-tension circuits in case one of the wires becomes disconnected from its spark-plug. No safety spark-gap is shown in the diagram, it being omitted in order to keep the diagram as simple as possible. Safety spark-gaps will be shown in connection with the constructive forms of magnetos.

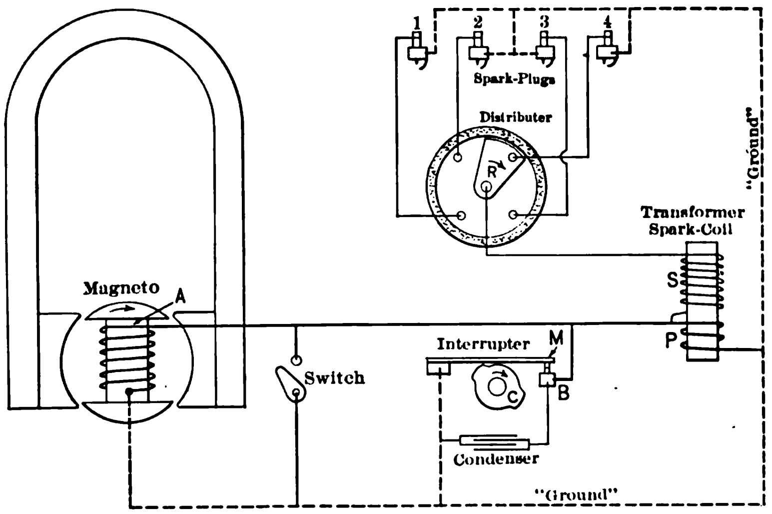


FIG. 223.

Jump-spark Ignition System with a Low-tension Magneto, a High-tension Distributer, a Separate Transformer and a Mechanical Interrupter in a Shunt Circuit.

178. Interrupted Shunt-current Magneto Ignition System. — Fig. 223. The primary circuit is never broken in this system. The interrupter is located in a shunt circuit which shunts the major part of the primary current away from the spark-coil during the time the interrupter contacts are closed.

During the rotation of the magneto armature from its zero-current position to its position of maximum current the interrupter is closed and most of the armature current is in consequence shunted from the spark-coil and passes through the

interrupter. When the magneto current is at or near its maximum value, the interrupter breaks the shunt circuit. This interruption of the shunt current, together with the action of the condenser, causes a sudden impulse of current through the primary winding of the spark-coil. The inductive action of this impulse current produces a momentary high-tension current in the secondary of the transformer. The high-tension current is distributed to the spark-plugs in the manner that has already been described.

Closing the switch keeps the shunt circuit permanently closed, thus cutting the spark-coil out of operation and stopping ignition.

179. Shunted-current Magneto Ignition System. — If the cam *C* in Fig. 223 is set forward on its shaft to the extent of about a quarter-revolution relative to the armature of the magneto, then one of the lobes on the cam would keep the interrupter contacts separated during the time the armature is rotating from its position of zero current to the position at or near maximum current. The position of the armature at maximum current is a little later than shown in the figure. The interrupter, or more properly contact-maker in this application, would then close the shunt circuit. The closing of the shunt circuit would divert the armature current from the spark-coil, through whose winding it flows while the contact-points of the interrupter are separated. The shunting of the armature current through the interrupter causes a sudden drop of current in the primary winding of the transformer spark-coil, and a high-tension current is consequently induced in the secondary of the spark-coil.

This system has the distinctive feature that the interrupter contacts can be separated at the instant when little or no current is flowing through the armature and interrupter. Burning and fusing of the contact-points, therefore, do not occur. Other features of the system seem to have prevented its coming into extensive use, however.

180. High-tension Magneto with Single-wound Armature. — If all of the apparatus except the spark-plugs and switch of the preceding figures of this chapter are assembled in one piece of apparatus, the combination is a high-tension magneto, since it

will deliver high-tension current suitable for jump-spark ignition without the aid of any exterior apparatus for generating the high-tension current. High-tension magnetos of this type (with the transformer a part separate from the armature) are used to a considerable extent. The transformer in such cases is generally located in the space between the armature and the crown of the magnets.

181. Double-wound High-tension Magneto Ignition System.—Fig. 224. The magneto illustrated diagrammatically has an

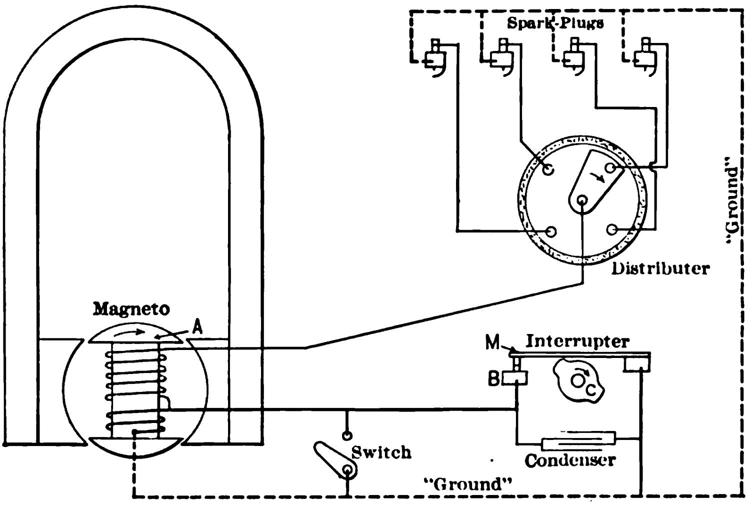


FIG. 224.

High-tension Magneto Connected to Spark-Plugs. A Complete Ignition System.

armature of the shuttle type with two windings, primary and secondary. The beginning of the primary winding is grounded by fastening the end of the wire to the core A of the armature, and the wire is wound over the entire core-neck next to the core. The end of the primary winding is connected to the beginning of the secondary winding, and the latter is wound over the primary. The high-tension terminal of the secondary winding is connected to the high-tension distributer. The junction of the two windings of the armature is connected to the stationary

FIGS. 226 and 227.

1. Insulated brass plate connected to one side of condenser.
2. Screw for fastening the complete interrupter (contact-breaker) in place. Insulated from the body of the armature and from the interrupter.
3. Insulated "stationary" contact-piece. Rotates with the armature.
4. Disk on which the interrupter parts are mounted. Not insulated.
5. Platinum contact-screw in 3.
6. Spring for pressing interrupter lever contact-point against the "stationary" contact-point.
7. Interrupter (contact-breaker) lever. Not insulated.
8. Condenser.
9. Insulated slip-ring connected to the high-tension terminal of the armature winding.
10. Carbon brush which presses against slip-ring 9.
11. Brush-holder for 10. Of insulating material.
12. Connecting bridge.
13. Carbon brush for carrying current to high-tension distributer.
14. Rotor of distributer.
15. Distributing brush for making contact with the stationary contact-pieces of the distributer.
16. Stationary insulating piece of the distributer.
18. Ends of high-tension cables for making connection to the spark-plugs.
19. Fiber rollers against which the end of the interrupter lever strikes so as to separate the contact points of the interrupter.
20. Arms to either of which the hand-control for regulating (advancing and retarding) the ignition can be connected.
21. Dust-cover above armature.
22. Vulcanite cover for distributer.
23. Three-arm spider. Not insulated
24. Terminal for ground wire to hand-switch. Insulated.
25. Spring for holding cap 26 in place.
26. Brass cover cap for interrupter. Insulated.
27. Brass block for supporting 25.
29. Platinum contact-screw in interrupter lever 7.
30. Stop-screw to limit the rocking movement of the interrupter casing when advancing or retarding the ignition.

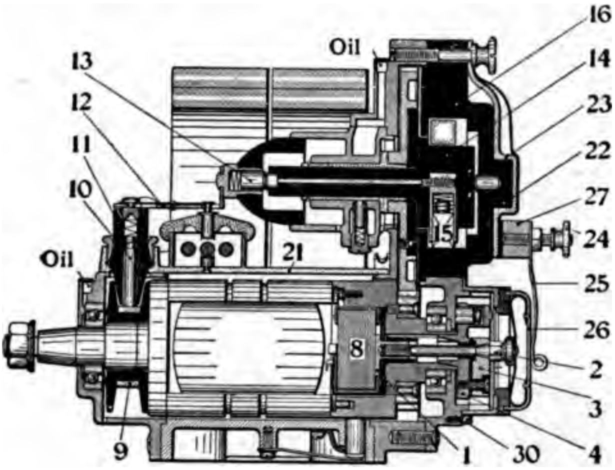


FIG. 226.

Longitudinal Section of Fig. 225.

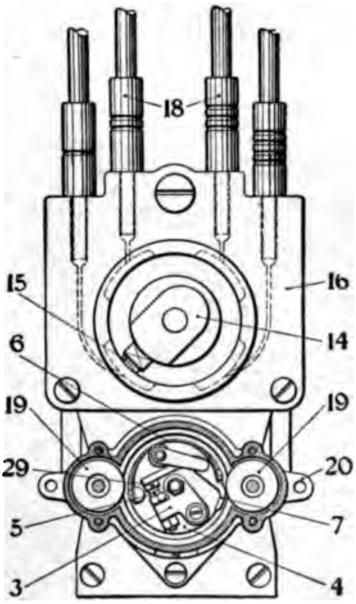


FIG. 227.

Interrupter End of Fig. 225 with Covers removed.

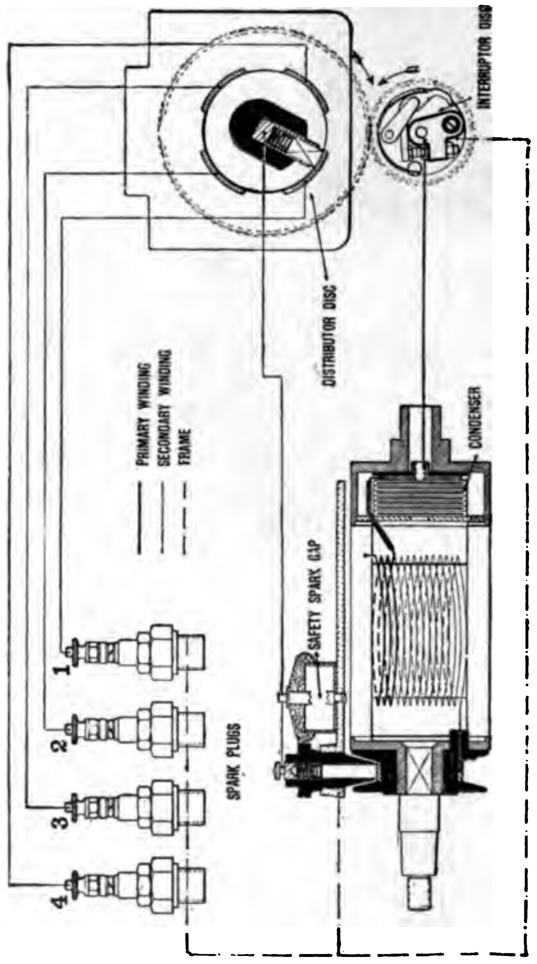


FIG. 228.
Ignition System Connections for Magneto Shown in Figs. 225, 226 and 227.

The beginning of the secondary winding of the armature is connected to the end of the primary winding. The high-tension terminal of the secondary winding is connected to the insulated slip-ring 9 against which bears the carbon brush 10. This brush is carried by the insulating brush-holder 11. The carbon brush 10 is connected to the insulated central spindle and carbon brush 15 of the distributer by means of the metal connector 12 and carbon brush 13. The brush 15 is carried by the insulating material 14 of the distributer rotor. The distributer brush 15 makes contact successively with metal contact-pieces set into the insulating piece 16. These contact-pieces are connected to terminals into which fit terminals 18 for the wires that go to the spark-plugs.

When the magneto armature is rotating, together with the interrupter disk and the parts attached to it, the end of the interrupter lever (right-hand end in Fig. 227) strikes first one and then the other of two fiber rollers 19. The striking of the end of the lever against the rollers causes the contact-points of the interrupter to separate and thus break the primary circuit. This causes a spark to jump at the spark-plug with whose terminal the distributer is in contact at the instant.

The part carrying the fiber rollers 19 can be rocked slightly relative to the frame of the magneto, in order to advance or retard the ignition. Two arms 20 are provided for this purpose. The rocking can be done by the hand-control, which is connected to one of the arms 20.

For cutting out ignition, the terminal 24 is provided. This terminal is insulated and connected to the insulated junction of the primary and secondary windings by means of the spring 25 that presses against the insulated metal cap 26. The latter carries a spring-mounted carbon button, or brush, which bears against the outer end of the metal screw 2. The screw is connected to the junction of the two windings, as has been stated. If a wire is led from the terminal 24 to one side of a hand switch, whose other side is grounded, then the closing of the switch will keep the primary circuit of the magneto permanently closed and thus prevent sparking at the spark-plugs. Under this

Plate I.

Magnets and End Plates.

30. Stop screw for timing-lever 20.
31. Magnet casing, pole-shoes, and base-plate (only 2 double magnets for "DR3," "D.R.4" and 2 single magnets for "DR6," not 3 as shown).
32. Long magnet-screws.
33. Short magnet-screws.
34. Holding down screws for pole-shoes to base-plate.
35. Front end-plate.
36. Long screws for front end-plate.
37. Short screws for front end-plate.
38a. Oil cover (with arrow ←) for front end-plate.
38b. Oil cover (with arrow →) for front end-plate.
39. Oil cover screw for front end-plate.
40. Spiral spring for oil cover screws 39 and 50.
41. Ball-race collar for ball bearings.
42. Rear end-plate without screws.
43. Screw for rear end-plate.
44. Screw for bearing flange 53 and 56.
45. Rear end-plate cover.
46. Long screws for 45.
47. Short screws for 45.
48. Left-hand oil lid for 45.
49. Right-hand oil lid for 45.
50. Oil-lid screw for 45.
51. Paper strip for ball race in both end-plates.
52. Paper washer for ball race in both end-plates.
53. Flange with oil lid and ball-race collar for two ball bearings.
54. Ball-race collar for flange 53.
55. Paper for ball-race collar 54.
56. Flange with slide bearing, oil wick and oil cover.
57. Oil-wick screw for flange 56 with wick spring and packing washer.
58. Wick screw only without parts.
59. Felt wick and spiral spring.
60. Leather washer for wick screw.
61. Oil cover for flange 53 and 56 for type "DR4."
62. Oil-cover screw for flange 53 and 56 for type "DR4."
63. Spiral spring for oil-cover screw 62.
64a. Oil cover left upperside on rear end-plate for type "DR6."
64b. Oil cover right upperside on rear end plate for type "DR6."
65. Screw for oil cover 64a and 64b.

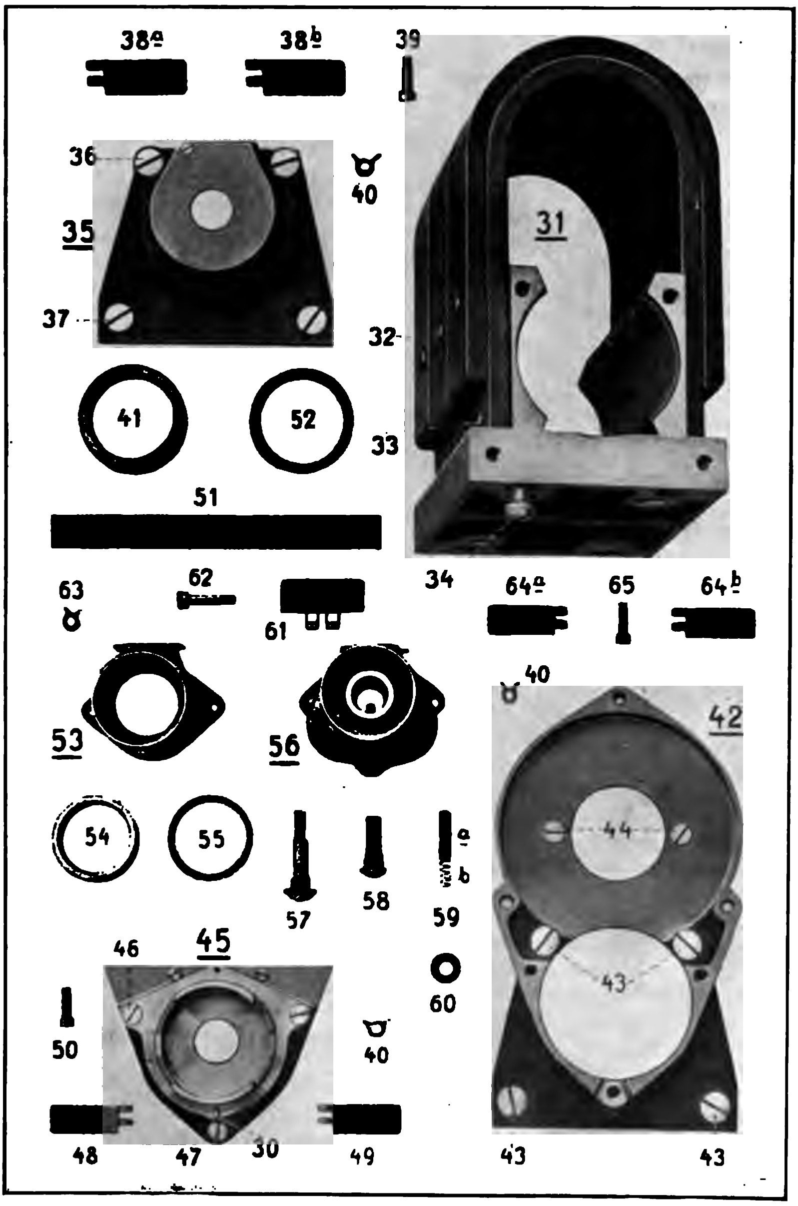


PLATE I. Parts of Fig. 225.

Plate II.

Armature and Contact Breaker.

1. Rear condenser-plate with insulator 78.
2. Contact-breaker screw.
3a. Platinum-screw block for anti-clockwise machines.
3b. Platinum-screw block for clockwise machines.
4a. Complete contact-breaker for anti-clockwise machines.
4b. Complete contact-breaker for clockwise machines.
5. Long platinum screw.
6. Contact-breaker spring.
7a. Contact-breaker bell-crank lever for anti-clockwise machines.
7b. Contact-breaker bell-crank lever for clockwise machines.
8. Condenser with connections and paper insulation binding.
9. Slip-ring for armature.
29. Short platinum screw.
66. Complete armature with pinion, slip-ring, condenser, and two ball-race rings, without ball-race collar.
67. Front armature-disk.
68. Fastening screw for 67.
69. Rear end insulation for slip-ring.
70. Front insulation for slip-ring.
71. Washer for shaft cone $\frac{3}{8}''$.
72. Nut for shaft cone $\frac{3}{8}''$.
73. Rear armature-disk.
74. Fastening screw for rear armature-disk.
76. Ebonite insulating plate for the condenser.
78. Insulation button.
79. Insulation silk.
80. Front condenser-plate.
81. Condenser screw.
82. Small hexagon nut for the condenser.
83. Washer for 82.
84. Insulating strip for condenser.
85. Small gear wheel on armature disk.
86. Fastening screw for gear wheel 85.
87. Inside ball-race ring for the ball bearings.
88. Cage for balls suitable for both ball bearings.
89. Felt disk for packing the one end of the armature.
90. Screw for contact-breaker spring.
91. Washer for 90.
92. Nut for long platinum screw.
93. Insulation for contact-piece on contact-breaker.
94. Insulation bush for 93.
95. Screw for contact-piece on contact-breaker.
96. Insulation bush for center of contact-breaker disk.
97. Flat spring pressing on to bell-crank lever.
98. Washer for 97.
99. Carbon brush for the contact-breaker.
100. Spiral spring for 99.

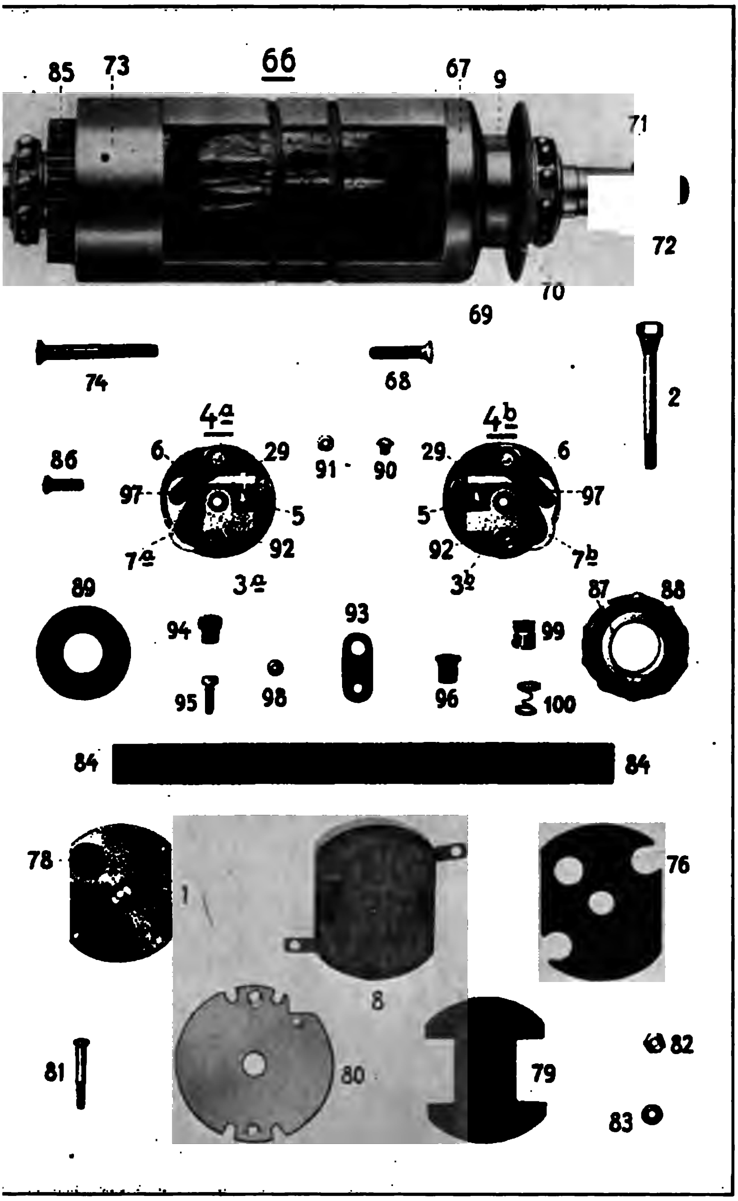


Plate II. Parts of Fig. 225.

Plate III.

Current Collector, Distributer, and Timing Lever.

10. Carbon brush with spiral spring for carbon-holder 11.
11. Carbon-holder without carbon and spiral spring.
11a. Carbon-holder with carbon and spring.
12. Complete connecting bridge with carbon-holder (brass) together with insulation piece and lock spring.
13. Carbon with spring for brass holder on connecting bridge 12.
14. Rotating distributer piece without carbon and spring.
14a. Rotating distributer piece with carbon and spring.
15. Carbon with spiral spring for rotating distributer piece.
16. Distributer disk without screws.
18. High-tension cable 800 mm. long with terminal, brass plug and insulating sleeve.
18a. Brass plug with ebonite insulating sleeve only for cable 18.
19. Fiber rollers for advance and retard lever 20.
20. Complete timing lever with fiber rollers.
21. Dust-cover only with cap for safety gap.
22. Ebonite cover for distributing disk 16.
23. Complete triangular clamp for the distributer disk together with brass connecting piece and spring.
23a. Clamp only without parts.
24. Rundled nut for switch wire (short circuit).
25. Spring for brass cap 26.
26. Brass cap for timing lever 20 together with carbon and spring.
27. Brass block for spring 25.
28. Fixing or head bolt for fixing spring 25.
30. Stop screw for timing lever 20.
101. Bell-shaped insulation piece on the connecting bridge 12.
102. Spiral spring for carbon 13.
103. Steatite cover for safety-gap together with electrode 104.
104. Electrode of steatite cover for spark-gap.
105. Screw for fixing the dust-cover 21.
106. Spiral spring for carbon 10.
107. Insulating ring for brass cap 26.
108. Cover for fiber rollers in advance and retard lever 20 together with steel stud 109.
109. Steel stud for fiber rollers in timing lever 20.
110. Fixing screw for cover 108.
111. Top screw for terminal block and clamp.
112. Bottom screw for terminal block and clamp.
113. Spiral spring for carbon 15.
114. Insulating plate for connecting piece 27.
115. Insulating bush for connecting piece 27.
116. Fixing screw for connecting piece 27.
117. Washer for spring 25.
118. Complete distributing gear wheel together with shaft and catch plate.
119. Fiber ring riveted on the distributing gear wheel (former execution).
120. Shaft for distributer gear wheel.
121. Fixing screw for shaft of distributer gear wheel.
122. Inside ball-race ring for the ball bearings fixed to shaft 120.
123. Cage with steel balls.
124. Spring ring at front end of the shaft 120.
125. Ebonite catch-plate.
126. Fastening screw for catch-plate 125.

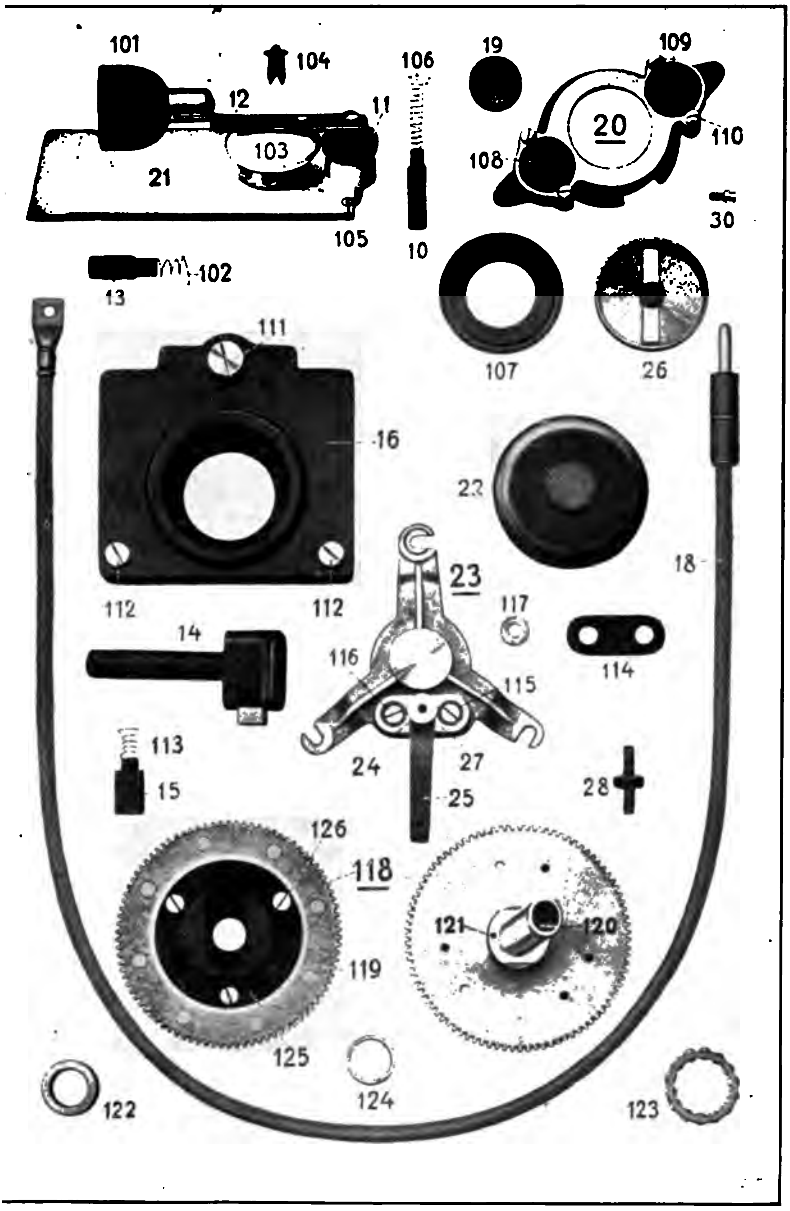


PLATE III. Parts of Fig. 225.

Plate IV.

For Newer Designs.

1a. Rear condenser-plate for condenser 8a.
2a. Contact-breaker screw. (Only suitable for armature with rear shaft and disk 73a.)
8a. Condenser with connection and connecting plate 1a. (Only suitable for armature shaft and disk 73a.)
9c. Slip-ring in one piece, without thread. (Only suitable for armature shaft and disk 67a.)
11b. Carbon-holder without thread, with spiral spring and carbon. (Only suitable for dust-cover 21a.)
11c. Carbon-holder without thread, minus spiral spring and carbon. (Only suitable for dust cover 21a.)
21a. Dust-cover with ball clip fastening, without any other parts. (Carbon-holder minus thread No. 11b is suitable for this cover.)
21b. Dust-cover with ball clip fastening, without any other parts. (Carbon-holder with thread 11 on illustration 111 is suitable for this cover.)
42a. Rear end-plate with center lubrication.
45b. Rear end-plate cover for center lubrication. (Only suitable for rear end-plate 42a.)
47. Short screw for 45b.
67a. Front armature shaft and disk minus thread on shaft (slip-ring 9c is suitable for this).
73a. Rear armature disk with protecting of condenser.
210. Bent steel washer for fastening slip-ring 9c.
211. Brass nut on dust-cover 21a for fastening carbon-holder 11b.
212. Body carbon with cable for base plate of magnet casing.
213. Screw for fastening body washer to base plate of magnet casing.
214. Washer for screw 213.
215. Flat spring to keep body carbon 212 in position.
216. Fastening screw for flat spring 215.
217. Washer for screw 216.
218. Strengthening spring for bell-crank lever 7a and 7b.
219. Strengthening spring on projecting brass lug of the contact-breaker disk 4c.
220. Oil-paper strip to fix condenser 8a on rear armature shaft and disk 73a.
221. Felt strip to fix condenser 8a on rear armature shaft and disk 73a.
222. Linen strip to insulate condenser 8a.
223. Pressed linen insulation for condenser 8a.
224. Fastening screw for condenser 8a.
225. Insulating bush on connecting plate on condenser 8a.

PLATE IV. Parts of Fig. 225.

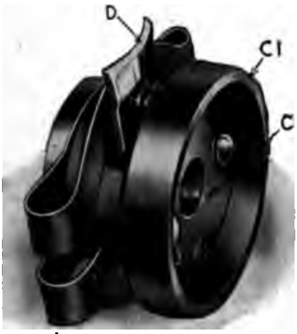


FIG. 230.

Interrupter for Fig. 229.

FIGS. 229, 230, and 231.

A. Timing lever and cam lobes.
B. Clip-spring for holding timer cover in place.
C. Steel disk of interrupter.
C 1. Slip-ring for the short-circuiting cut-out.
D. Interrupter arm.
d. Barrel of interrupter, bronze.
E. Spring on which the interrupter arm is mounted.
e. Centering disk, steel.
F. Socket for hinge pin of interrupter lever.
f. Contact-points of interrupter.
G. Nut for holding the interrupter in place.
H. Insulated stud.
h. Cover plate of condenser.
I. Brush-holder and terminal for the short-circuiting cut-out.
J, J. Cam lobes.
P. Distributer cover.
R. Clip-spring for holding distributer cover in place.
S. Distributer plate, of insulating material.
T. Distributer brush.
t. Distributer shaft.

condition there can be no sudden interruption of the primary current by the action of the interrupter. The variations of the primary current in the permanently closed circuit will not produce a spark at the spark-plugs.

A safety spark-gap is provided in the secondary circuit. It is shown in Fig. 226 between the insulated connecting strip 12 and the grounded dust-cover 21 which is just over the armature. One spark-point of the safety-gap is connected to the insulated

FIG. 231.
Device for Setting the Interrupter of Fig. 229.

conductor 12; the other spark-point is connected to the dust-cap. The safety-gap is enclosed by a short, tubular piece of metal and a steatite cap on the top of the short tube, together with a porton of the dust-cap. The tubular piece has several holes leading to the atmosphere. These holes have fine-mesh wire gauze over them to prevent the ignition of gasoline vapor outside of the safety-gap inclosure, in case such vapor should happen to gather around the magneto to an amount that makes a combustible mixture with air.

"Ground" connection between the body of the armature and the frame of the magneto is made certain by a carbon brush

which presses against the metal of the armature. This brush is shown just beneath the casing of the condenser in Fig. 226. It is connected to the base-plate of the magneto by a short electric cable that is fastened to the base-plate by a screw. A flat spring presses against the outer end of the brush to keep the latter in contact with the armature. The brush with the attached cable is shown at 212 in Plate IV, together with the other parts, 213, 214, 215, 216, and 217, for making the ground connection. In some magnetos, the bearings in which the armature spindle rotates are depended upon to make the ground connection of the armature to the frame of the magneto, but this is not an entirely reliable means, for oil and dirt in the bearings may at times cause imperfect contact between the spindle and the supporting part of the bearing.

183. U. & H. (Unterberg & Helmle) Magneto with Rotary Double-wound Shuttle Armature. — In Fig. 229 this machine is shown with some of the parts removed to make clear the construction. The interrupter is also shown separately in Fig. 230.

The electric connections of this magneto are the same in effect as those shown in Fig. 224.

The interrupter is of unusual design. Referring to Fig. 230, the contact-points are shown at *f*. The stationary contact-point is connected to the electrically insulated steel disk *C*, upon which the slip-ring *C*1 is mounted and electrically connected to it.

The movable contact-point is attached to an interrupter arm *D* which is mounted on an elastic member *E* that is bent back upon itself so as to form a spring of suitable form to carry the interrupter arm. *E* is fastened between a steel centering disk *e* and a cylindrical bronze part or barrel *d*. An insulated socket *F* is provided for the rounded end of a hinge pin in the interrupter lever *D*.

The interrupter lever *D*, the elastic member *E*, and the parts *e* and *d* are electrically connected together. When the interrupter is in place on the magneto these parts make connection with the grounded side of the armature.

The curved portion of the interrupter arm which is shown

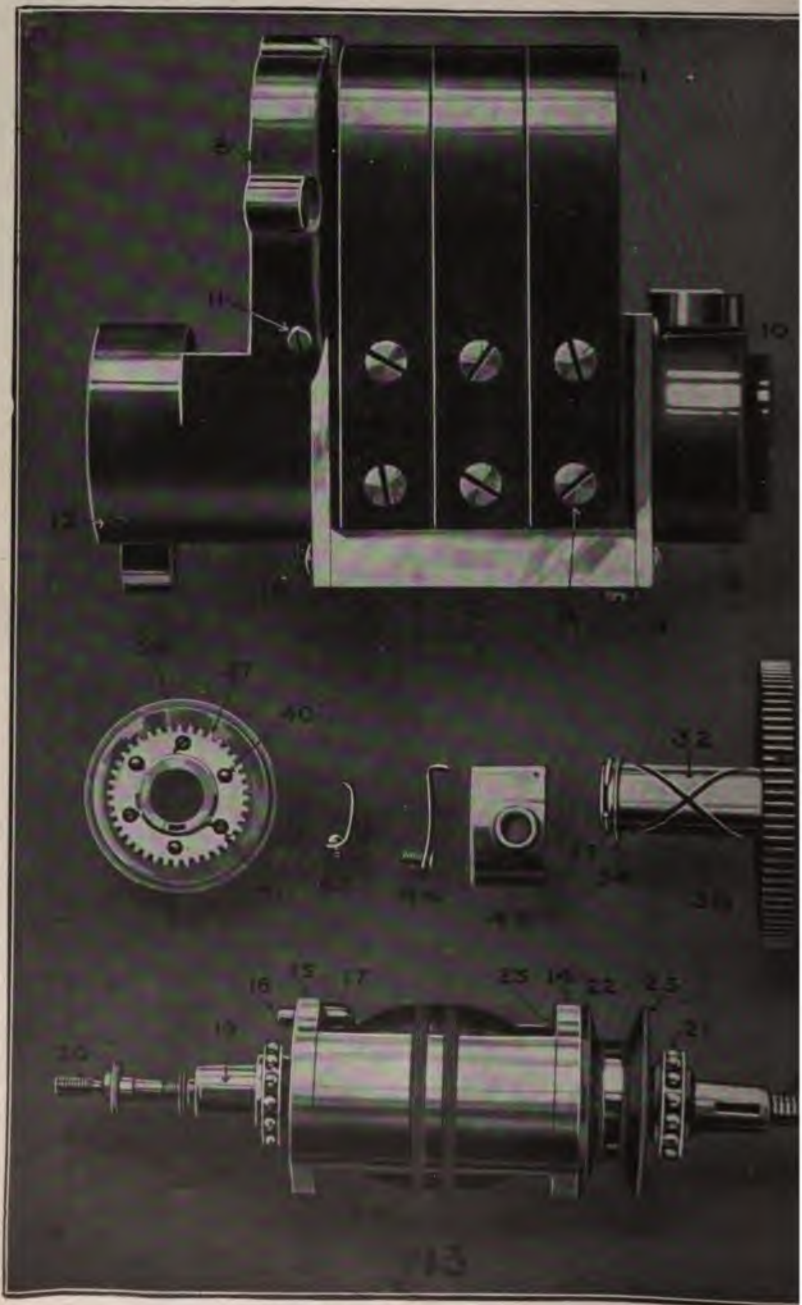


PLATE V. Parts of Fig. 229.

projecting at the upper part of the illustrations strikes against the lobes of a cam as the armature rotates, so as to move the lever back and separate the contact-points. These lobes are shown at *J* and *J* in Fig. 229. They are attached to the cam-piece *A*, of which the timing lever for connecting to the spark control is a part.

When the interrupter is in place the centering disk *e* bears against one of the cover-plates *h* of the condenser which lies between the interrupter and the winding of the armature.

The interrupter is held in place by a nut *G* which screws on the insulated stud *H*, that is connected to the junction of the primary and secondary windings of the armature. The insulated disk *C*, bronze slip-ring *C*1, and the stationary interrupter point are thus connected to the junction of the two windings.

The beginning of the primary coil of the armature winding is grounded to the armature core. The end of the secondary winding is connected to a slip-ring at the end of the armature next to the driving gear. This slip-ring is shown in Plate V.

The high-tension current is carried from this slip-ring through a brush and suitable connections to the distributer brush *T*, which is rotated in the usual manner by a pair of gears that connect the shaft which drives *t* and its brush-holder for *T* to the armature shaft. The brush and brush-holder are shown drawn partly out from the recess in which they properly belong. The distributer plate *S* is of insulating material and has four contact-pieces against which the distributer brush *T* rubs successively during its rotation.

When in proper position the interrupter rotor is protected by the cover *P* which is held in place by the clip *R*.

The cam-piece *A–J* fits into the cylindrical housing on the interrupter so as to bring the lobes *J* into the proper position for the curved end of the interrupter arm *D* to strike them. The rocking movement which can be given to the cam-lobes in order to advance and retard the ignition, is limited by a small stop shown in the inside of the cylindrical housing in the right-hand lower part. The rocking part *A–J* is held in place by the clip *B*.

The brush-holder *I* fits into the threaded opening shown at the left-hand upper part of the interrupter housing. The brush in this holder bears against the slip-ring *C*1. This brush-holder forms the ground terminal which is to be connected to a switch that remains open while the magneto is operating, but is closed in order to stop the operation of the magneto. Connecting the ground terminal to ground in the manner just stated short-circuits the primary winding of the magneto.

A safety spark-gap is provided between one of the high-tension connections and the grounded dust-plate which goes just above the armature. The safety-gap is inclosed by porcelain and metal walls, the latter being perforated, so as to form openings through which a spark passing between the points can be seen. The openings of the metal are provided with mica windows for the exclusion of vapor and dust.

A convenient manner of holding the interrupter in proper position during the process of timing the magneto is by means of the pin shown in Fig. 231. This pin passes through a small hole in the cam-piece *A* and enters a hole *Z* in the interrupter. The hole in the part *A* is closed by a screw during the operation of the magneto.

This magneto, in some of its types, is provided with a *starting device* which enables a motor to be started on magneto spark without the necessity of cranking, or otherwise rotating the motor, at a speed any higher than is necessary for battery ignition with a trembler spark-coil. Briefly, the magneto is driven by means of a device containing a stout spring and a loose ball. When the driving mechanism is rotated slowly, the ball locks the armature so that it cannot rotate until after the spring has been wound up to some extent. The ball then strikes a part which throws it out of its locking position, and the armature is rapidly rotated by the spring far enough to produce a strong ignition spark. As soon as the motor starts on its own power, the speed of the mechanism that drives the magneto is high enough to prevent the ball from dropping into its locking position, and the armature is then driven continuously at the speed of the driving mechanism.

184. Remy Magneto with Stationary Armature and Rotary Inductor. — Fig. 232 is a full view of the magneto. Fig. 233 is a photographic end view, and *A* of Fig. 236 is a line-drawing end view; the covers of the interrupter and distributer are removed

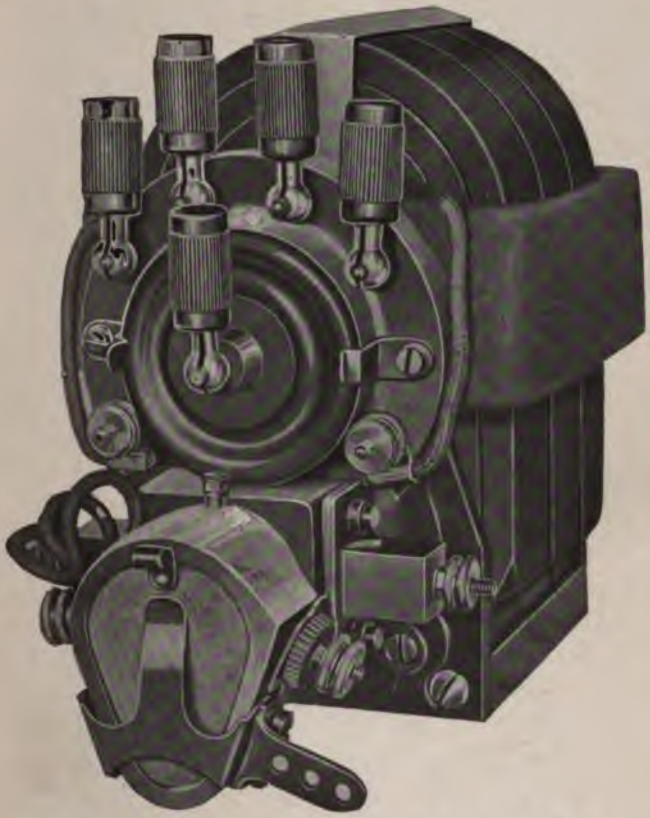


FIG. 232. (*See also* Figs. 233, 234, 235, 236, and 256.)

Remy Magneto with Stationary Single-wound Armature and Rotary Inductor. Remy Electric Company, Anderson, Indiana.

in both of these views. Sectional views are shown in Figs. 234 and 236. The armature winding and the inductor are shown in Fig. 235.

The armature winding 1 is a single-wound circular coil. It has

several turns of rather coarse insulated wire. The coil encircles an enlargement of the inductor shaft 2, which has fastened to it (by pins) two forged steel arms, or wings, 3 and 4. These

FIG. 233.

Interrupter End of Fig. 232 with Cover-Plates removed.

wings, together with the enlarged portion of the shaft, form the rotary inductor of the magneto. The form and disposition of the wings can be seen by examining Figs. 234, 235, and 236.

The wings extend in opposite directions from the shaft, and the outer end of each wing is crowned cylindrically to conform to the concave surfaces of the magnet-poles between which they revolve. One of the magnet-poles is shown in section at 5, Fig. 234. The armature coil is partly embedded in the magnet

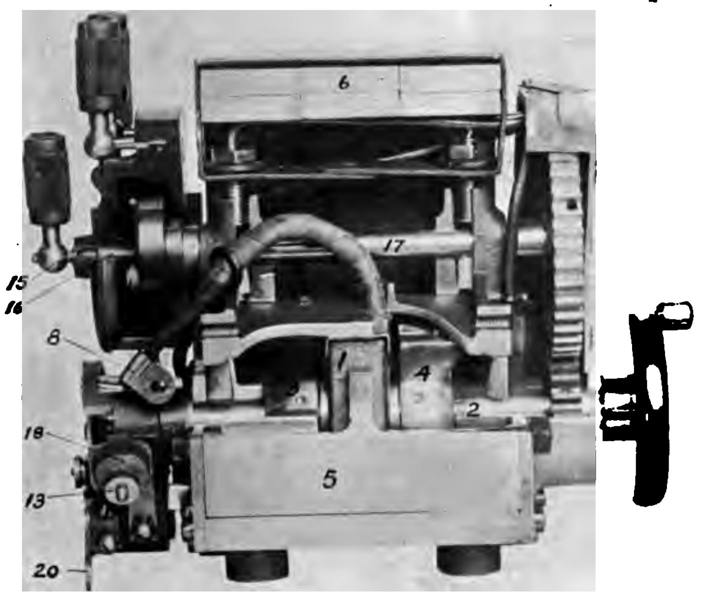


FIG. 234.
Longitudinal Section of Fig. 232.

poles. The magnets 6 are of the ordinary U-shaped compound type. One end of the armature coil is connected to the grounded terminal 7; the other end is connected to the insulated terminal 8, from which, in an ignition system, a wire leads to a non-trembler spark-coil, or to a switch connected to the spark-coil.

Each revolution of the inductor produces two impulses of alternating current in the armature coil. The direction of magnetic flux through the inductor during each revolution is first

from the north pole of the magnets to and through the inductor wing 3, thence through the enlargement of the shaft and on through the wing 4 to the south pole of the magnets. After half a revolution of the inductor, the magnetic flux is from the north pole of the magnets to the inductor wing 4, enlarged portion of the shaft, wing 3, and the south pole of the magnets. The

FIG. 235.
Rotary Inductor and Stationary Armature Coil for Fig. 232.

magnetic flux is thus reversed in its direction of flow through the armature coil twice each revolution.

The interrupter rocker-arm, or rocker-lever, 9, is kept pressed against a two-lobed cam 10 by means of a coiled compression spring 11. The cam is fastened to the inductor shaft and rotates with it. The rocker-lever has two arms, to one of which is fastened the blade-spring 12. The movable contact-point of the

FIGS. 232, 233, 234, 235, and 236.

1. Armature Coil.
2. Inductor shaft.
3, 4. Wings of Inductor.
5. Magnet pole.
6. Magnets.
7. Grounded terminal of armature coil.
8. Insulated terminal of armature coil.
9. Interrupter rocker-lever.
10. Interrupter cam.
11. Compression spring.
12. Blade springs.
13. Insulated terminal of interrupter.
14. Metallic part of distributer rotor, insulated.
15. Central terminal of distributer.
16. Central contact carbon of distributer.
17. Distributer shaft.
18. Adjusting screw of interrupter contacts.
19. Hammer end of interrupter lever.
20. Arm for rocking the interrupter.

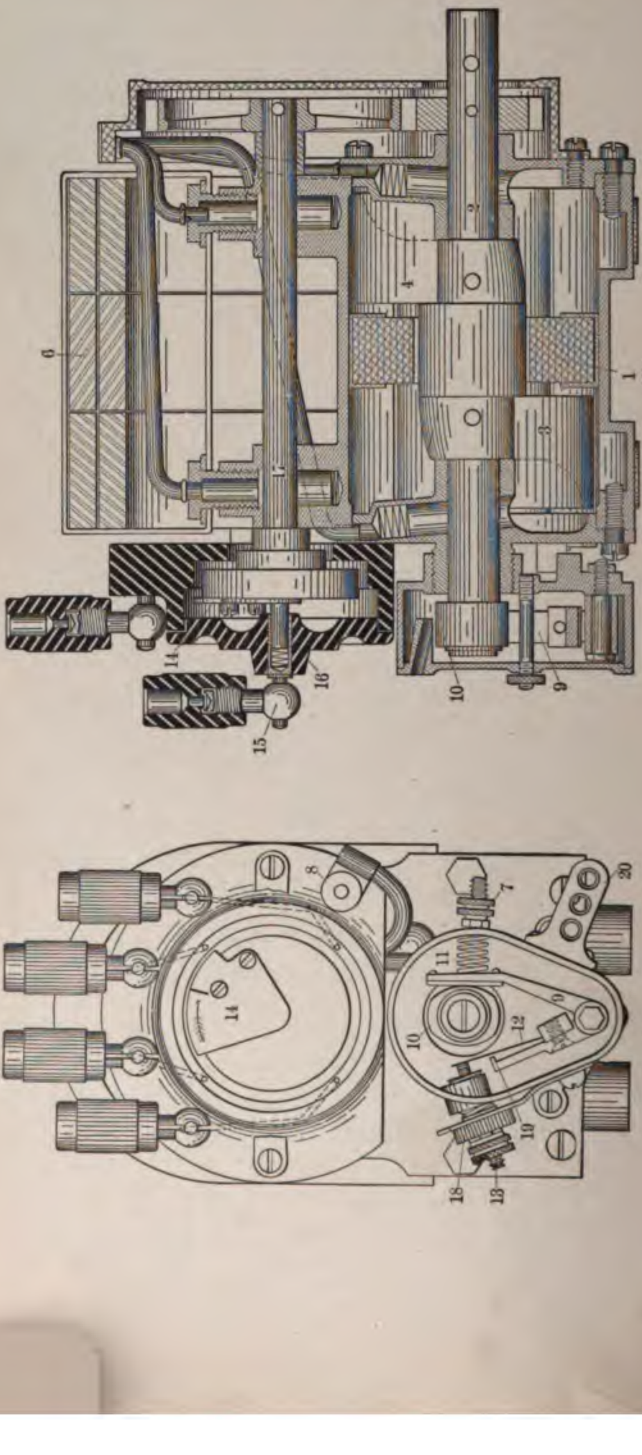


FIG. 236.
Interrupter End and Longitudinal Section of Magneto of Same Type as Fig. 232.

interrupter is fastened to the free end of the blade-spring. When the cam is in the position shown in Fig. 236, the movable contact-point is pressed against its mating stationary contact-point, which is an extension of the insulated terminal 13. As the cam rotates, it forces the rocker-lever back against the resistance of the coiled compression spring and causes separation of the contact-points so as to break the armature circuit. Quick separation of the contact-points is secured by means of the striking end 19 of the interrupter lever.

The stationary contact-point can be adjusted by turning the screw in which it is mounted. A knurled piece of insulating material 18 is provided for making this adjustment. The arm 20 is provided for rocking the entire interrupter by hand to advance and retard the time of ignition.

The distributer has high-tension current brought to its insulated metallic rotor 14 from the spark-coil by means of a wire connected to the terminal 15. The latter is connected to the distributer rotor by the carbon contact brush 16. The rotor of the distributer is rigidly mounted on the shaft 17, which is driven by gears connecting it to the inductor shaft as shown. The distributer rotor directs the high-tension current successively to the four terminals shown at the upper part of the illustrations. In a complete ignition system, these terminals are connected to the spark-plugs that produce ignition in the motor.

185. Effect of Advance and Retard on the Strength of the Ignition Spark. — One much-used method of varying the instant of ignition (of advancing and retarding the spark) is to rock the entire interrupter relative to the rotor (armature or inductor) of the magneto. If the interrupter is rocked in the direction opposite the rotation of the rotor, the ignition spark is thereby advanced; or if the interrupter is rocked in the direction of rotation of the rotor, the spark is thereby retarded.

It has already been pointed out that the alternating electric current generated in the low-tension winding of a shuttle-wound armature as it rotates between magnet-poles is at or near its maximum value during only a very small portion of a revolution

of the armature or inductor. The same is true relative to other types of armatures in a bipolar alternating-current magneto. Therefore if the interrupter is rocked relative to the magnet-poles as well as relative to the armature, the primary current will be smaller at the instant of its interruption, when the ignition is either fully advanced or fully retarded, than when the interrupter is in an intermediate position. The result is that a weaker spark is obtained for ignition when the interrupter is advanced or retarded than when it is at an intermediate position. This weakening of spark strength is not so great, however, but that numerous excellent magnetos are in operation in which the advance and retard of the spark is obtained by rocking the entire interrupter relative to both the rotor and the magnet-poles, the latter remaining stationary relative to the frame on which the magneto is mounted.

On the other hand, various methods have been adopted in connection with interrupter magnetos, to secure an ignition spark of the same length for all settings of the ignition, from full advance to full retard. Of these methods, the chief ones are:

Rocking extensions of the magneto poles, to rock with the interrupter;

Rocking magnets;

Shaft couplings in which one part can be rotated by the spark-control mechanism, through a portion of a revolution relative to the other part;

Alternately charged and discharged condenser.

These methods are described in the following part of this chapter, either separately or in connection with a magneto.

186. Charged-and-Discharged Condenser Ignition System. — The magneto for this system has a condenser of comparatively large capacity. The armature has a low-tension winding only and there is a non-trembler spark-coil separate from the armature. The magneto has two devices of the nature of an interrupter, one of which will be called a circuit-closer, and the other an interrupter. An alternating current is generated.

During the operation of the magneto, the condenser is first

connected to the armature of the magneto through the closed interrupter until the condenser becomes charged. The interrupter then breaks the connection between the armature and condenser at about the instant of maximum voltage in the armature, thus leaving the condenser charged on open circuit. Then, at the instant of ignition, the circuit-closer closes the circuit between the spark-coil and the condenser. The condenser discharges through the primary of the spark-coil as soon as the condenser-transformer circuit is closed. The discharge current from the condenser acts to produce an ignition spark at the spark-plug. Two ignition sparks per revolution of the armature are produced when the latter is of the ordinary shuttle-wound type and rotates between bipolar magnets.

The breaking of the armature-condenser circuit always occurs at the same instant with regard to the position of the armature relative to the magnet-poles. The condenser, therefore, always receives the same amount of charge, at a given speed of rotation of the armature, regardless of the time of ignition relative to advance and retard. Consequently, the condenser sends the same amount of current through the transformer whatever the time of ignition, at any given rotative speed of the armature. The strength, or hotness, of the ignition spark is the same whatever the time of ignition. A hotter spark is produced at high speeds of the armature than at low speeds, which is true of all magnetos.

187. Shaft Couplings for Advancing and Retarding the Ignition. — A form of coupling that is quite commonly used for this purpose consists of one or two pieces in which a helical slot or groove is cut, and another part having a key or pin which fits into the groove. By moving one part longitudinally relative to the other, rotation of the one relative to the other is caused to a limited extent. Thus, if the driving shaft is held from rotating, then sliding one part of the coupling along the other will cause the armature of the magneto to rotate through part of a revolution. If the interrupter is fixed in position (not constructed so as to rock) the instant of ignition will be changed by this movement of the armature. Moving the coupling so that the armature

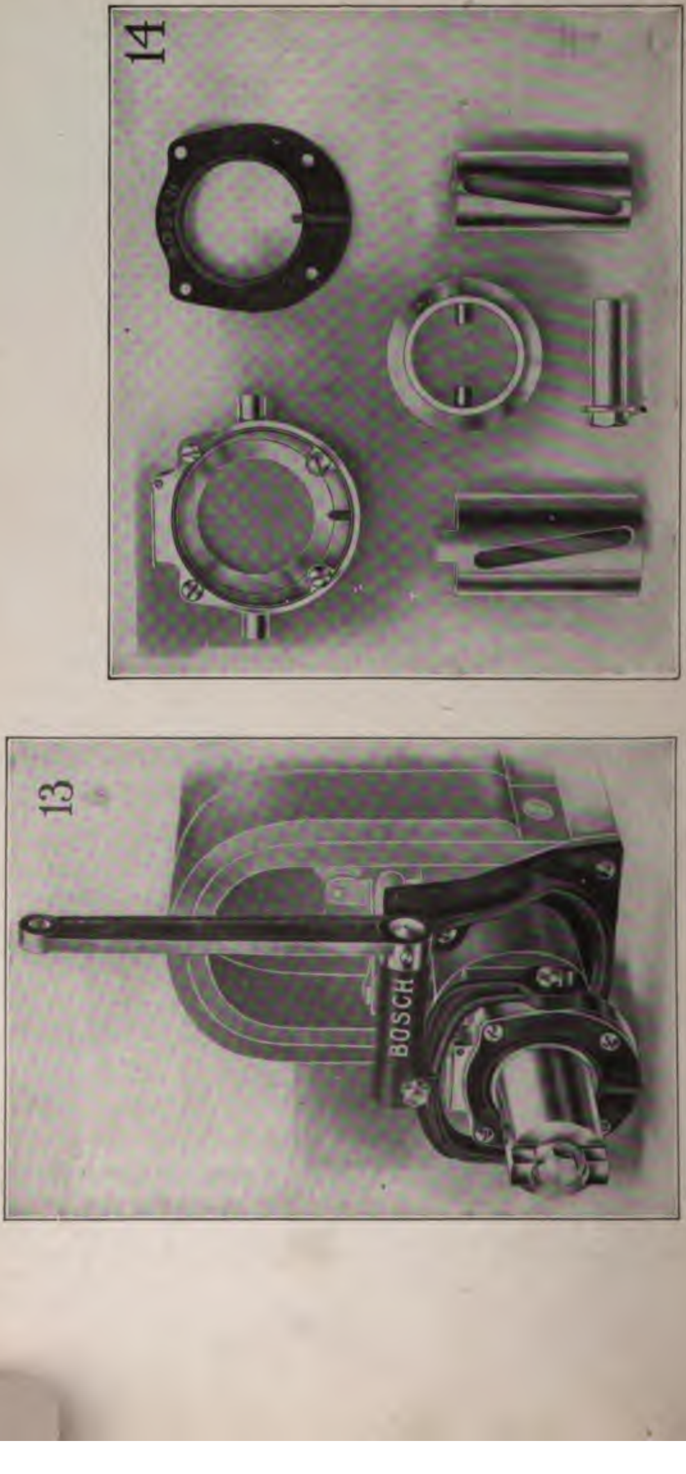


Fig. 237.
Parts of Helically-slotted Coupling for Advancing and Retarding Ignition, and the Coupling Applied to a Magneto.

is thereby rotated through part of a revolution relative to the driving shaft, in the direction that they run, advances the spark, and vice versa. Since the interrupter is not rocked relative to the magnet-poles, and is operated from the armature shaft, the armature is always in the same position relative to the magnet-poles at the instant that the interrupter breaks the primary circuit to produce a spark. A spark of uniform strength is therefore produced for all settings of the ignition from full advance to full retard, at any given speed of the armature.

One form of helically slotted driving coupling is shown both in detail and on the magneto in Fig. 237.

The smaller slotted tubular part is fastened rigidly to the armature shaft, and the larger slotted tube fits loosely over the smaller tube. The ring with two inward projecting pins fits over the larger tube, and the pins project through the slots in both tubes, thus preventing the rotation of one relative to the other. The ring is held in place longitudinally by the collar bearing shown in two parts at the upper portion of Fig. 237. The collar bearing has two trunnion pins to which the timing lever is connected for shifting the collar along the tubes.

Couplings of this nature are used for obtaining excessive advance of ignition, as on racing automobiles.

187.1. Eisemann High-tension Magneto with Automatic Spark-advance Mechanism. — The magneto has a double-wound armature of the shuttle type which rotates between pole-pieces in the usual manner, and a high-tension distributer for directing the secondary current to the spark-plugs in consecutive order as desired.

The device for advancing the ignition as the speed of rotation of the armature increases is shown in the right-hand portion of Fig. 238, which is a longitudinal section of the magneto. The armature is driven through a coupling which has a groove or grooves and a sleeve which, when moved longitudinally, causes the armature to rotate through part of a revolution relative to the driving shaft, which receives power from some external source. The method of obtaining automatic advance is to connect the weights of a centrifugal shaft-governor to the sleeve

of the coupling so that when the weights are thrown outward from the shaft by the centrifugal action due to the rotation of

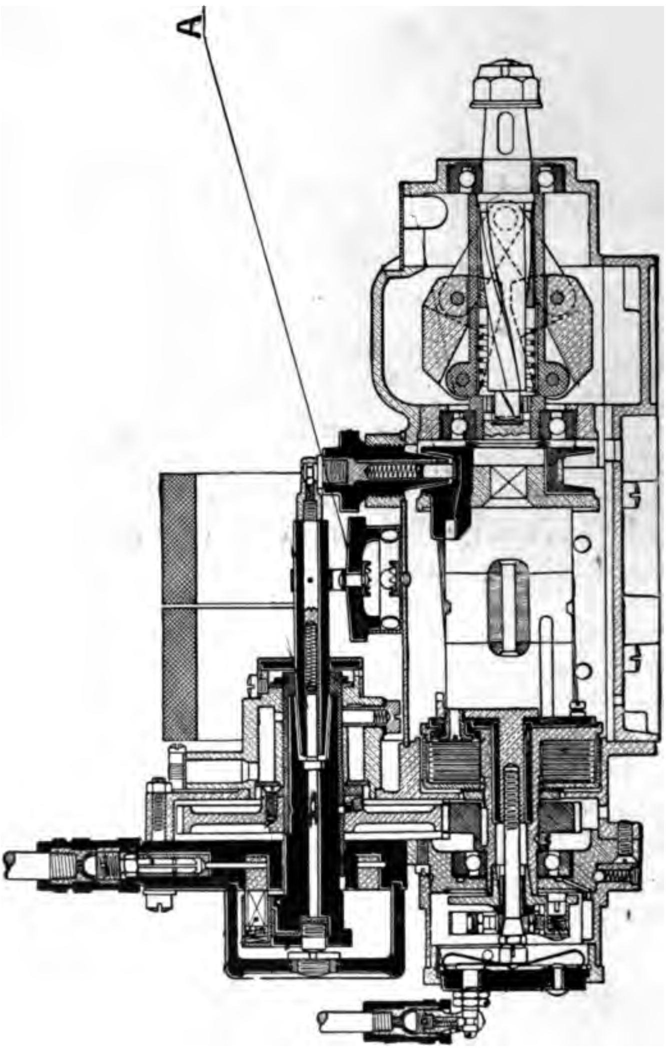


FIG. 238.
Eisemann High-tension Magneto with Advance and Retard Coupling Automatically Operated. The Eisemann Magneto Company, New York, N. Y., and Detroit, Michigan.

the armature, the movement of the weights slides the sleeve along the shaft so as to advance ignition. The safety spark-

gap A is shown distinctly in the illustration. The cylindrical metal which forms part of the inclosing wall of the space in which the safety-gap is inclosed is perforated with round holes as shown. These holes should be covered with wire gauze to prevent ignition of an inflammable mixture which may collect about the safety-gap, or with some such material as mica, for the same purpose and to exclude dust.

188. A magneto with a separately-wound induction coil that is embodied in the magneto is shown in Fig. 239. The end

FIG. 239. (*See also* Figs. 240, 241, and 242.)
High-tension Magneto with Separately-wound Transformer.

cover and several of the other parts are removed, including the interrupter lever and the distributer rotor. Fig. 240 is a sectional view of the magneto, and Fig. 241 shows most of the parts separately. The wiring diagram is given in Fig. 242. This magneto operates on the interrupted short-circuit system that is shown in Fig. 223.

The armature is of the shuttle type with one winding. The condenser 18 is just above the armature, and a non-trembler transformer spark-coil 10 is located between the condenser and the crown 11 of the magnets. The interrupter-lever is operated by a pair of rolls in the ends of the roll-carrier 25, which is rigidly fastened to the armature shaft. The beginning of the armature winding is grounded on the armature core. The end of the

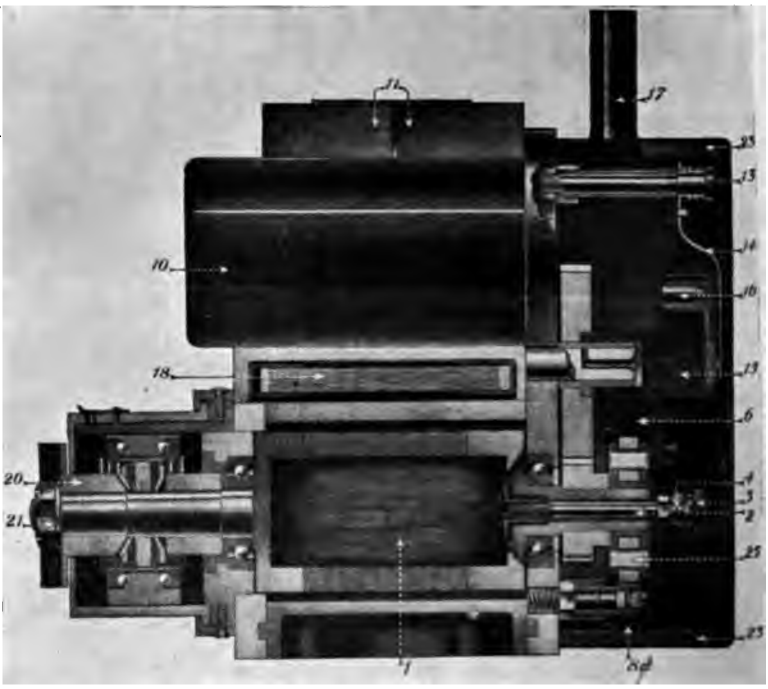


FIG. 240.

Longitudinal Section of Fig. 239.

1. Armature.
2. Insulated fastening screw connected to armature winding.
3. Primary bridge for carrying 4.
4. Contact-carbon pressed against 2.
6. Hard rubber block.
8. Stirrup spring for holding interrupter lever in place.
10. Transformer.
11. Magnets, crown of.
13. High-tension terminal of transformer.
14. Blade-spring connector between 13 and 15.
15. Distributer rotor.
16. Carbon brush in distributer rotor.
17. Terminals for wire cables.
18. Condenser.
20. Coupling for driving the armature.
21. Fastening nut for coupling.
23. Cover.
25. Roll-carrier of interrupter.

armature winding is connected to the insulated stationary contact of the interrupter, also to the primary of the spark-coil and one side of the condenser, so that the armature, interrupter, park-coil, and condenser are all four in parallel with each other. The high-tension current from the spark-coil is carried to the istributer rotor which directs it to the different spark-plugs in ie usual manner. A terminal is provided which connects to ound through a hand-switch. When the latter is closed, the mature circuit is permanently closed so as to cut out ignition.

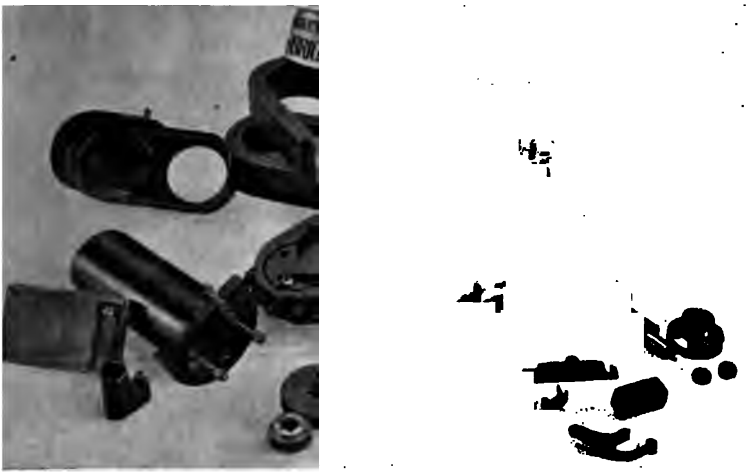


FIG. 241.
Parts of Fig. 239.

The armature is driven by means of a coupling which rotates ie armature through part of a revolution relative to the shaft hich drives it, when the spark-control is operated to advance r retard the ignition. The interrupter is permanently fixed in osition relative to the magnet-poles. The magneto, therefore, ives a spark of uniform strength at a given speed, whatever the tting of the ignition relative to advance and retard.

189. Movable Extension of Magnet-Poles for Constant trength of Spark. — This method of securing a nearly constant rength of the ignition spark for positions of advance and retard

of the ignition, at any given speed, has been applied to shuttle-wound magnetos. The more usual method of applying it is to make the bore of the magnet-poles considerably larger than the diameter of the armature, and insert a movable piece of magnetic material between each of the stationary poles and the armature. Ordinarily a longitudinal portion of a soft steel or iron tube is

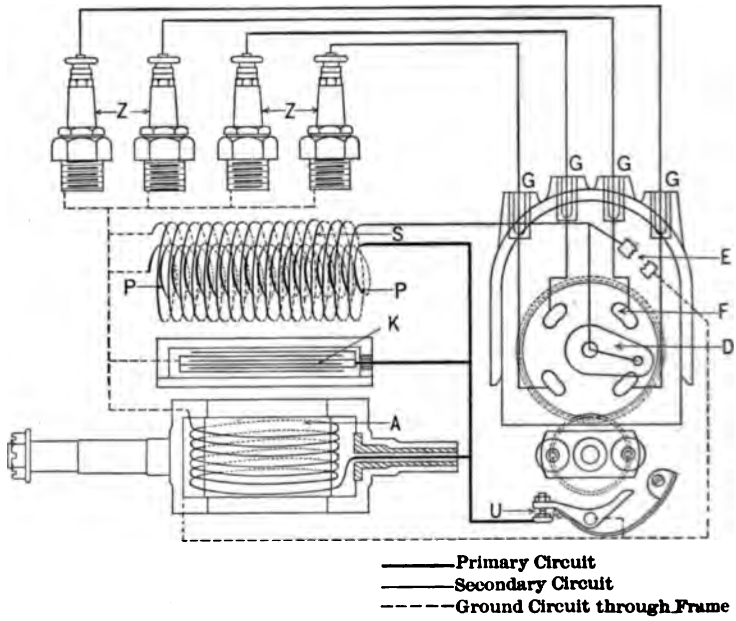


FIG. 242.

Connections of Eig. 239.

placed between each of the poles and the armature. The device in one of its forms resembles, in a measure, the rotating shield shown in Fig. 28 without the extension for a brush at one end.

Fig. 243 is a sectional view of the stationary magnet-poles, movable extensions of the poles, and the core of a shuttle-wound armature. The interrupter of the magneto and the movable extensions of the poles are fastened together so that they move as one piece when the interrupter is rocked to advance or retard the spark. The interrupter is set to break the circuit while the

armature is passing through the position, relative to the movable extensions of the poles, that is shown in the figure. In this position, the edges of the crowned surfaces of the armature core have passed a short distance beyond a position opposite the movable extensions 1 and 2 of the poles. This short distance is

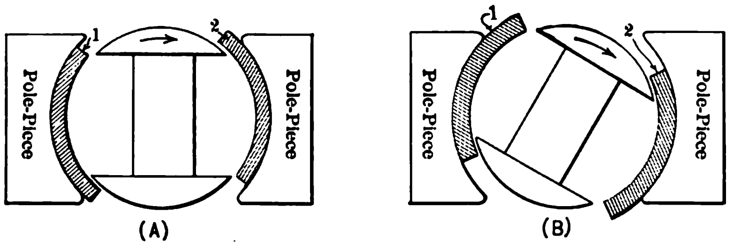


FIG. 243.
Movable Magnetic Shield between Pole-pieces and Rotary Armature.

about the same in amount in both (*A*) and (*B*), in which (*A*) represents the position of the pole extensions for advanced ignition, and (*B*) their position for retarded ignition.

The rocking of the pole extensions together with the interrupter has the effect, in a way, of carrying the magnetic field around with the interrupter when it is rocked. The armature is thus, in effect, in essentially the same position relative to the magnetic field when the interrupter breaks the circuit, whether the ignition is set early or late. The ignition spark is, therefore, of about the same strength for all positions of the interrupter from that for earliest ignition to that for latest ignition.

190. Pittsfield Magneto with Stationary Armature and Rocking Pole-Extensions. — Fig. 244 is an exterior view of the magneto. Fig. 245 is a longitudinal section. Fig. 246 shows the interrupter, and Fig. 247 is a cross-section on *A–B* of Fig. 245.

The construction of this magneto is unusual, in that the stationary coils 6 of the armature are not between the pole-pieces of the permanent magnets, but are wound around a soft iron or steel core 5 which is connected to two laminated soft iron or steel bars 4 that extend in between the poles of the permanent magnets 3. The laminated bars 4 are held rigidly in place by

non-magnetic parts 2 and the non-magnetic base of the magneto. These and the pole-pieces of the permanent magnets are bored cylindrical to fit a longitudinally slotted iron sleeve which has four slots so as to leave four bars 28. The inductor 1 rotates inside of the slotted sleeve. The inductor has the form of a thick tube slotted through from side to side, the width of the

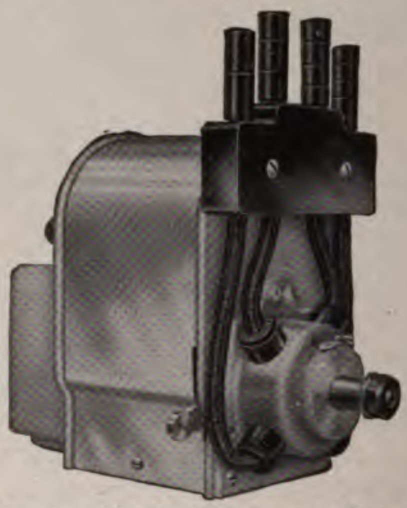


FIG. 244. (*See also* Figs. 245, 246, and 247.)
High-tension Magneto with Stationary Double-wound Armature, Rotary Inductor, and a Rocking Magnetic Shield between the Pole-pieces and the Inductor. Pittsfield Spark Coil Company, Dalton, Massachusetts.

slot being somewhat less than the inside diameter of the tube. The metal of the inductor is shown shaded in Fig. 247.

As the inductor revolves, it alternately directs the magnetic flux from the permanent magnets through the bars 4 and core of the armature windings and cuts off the flux through the armature core. While the inductor is in the position shown, the magnetism flows from the north pole-piece of the permanent magnets directly through the two sides of the inductor to the south pole-piece of the permanent magnets. When the inductor has rotated one-eighth of a revolution from the position shown, the magnetic flux is then from the north pole-pieces of the permanent magnets through the upper side of the inductor to the

upper bar 4, then through the upper bar to the armature core 5, down through the armature core to the lower bar 4, and through this bar to the lower side of the inductor, and on through this side of the inductor to the south pole-piece of the permanent magnets. The magnetic flux is of course through the slotted tube, or magnetic shield, 28, when going from the inductor to or from the pole-pieces and bars 4. When the indicator has rotated

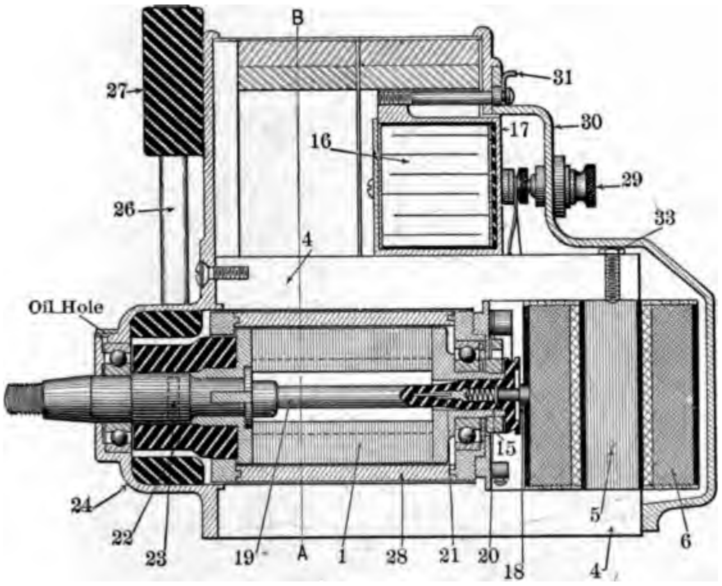


FIG. 245.
Longitudinal Section of Fig. 244.

a quarter-revolution from the position shown, there is no magnetic flux through the armature core. At three-eighths of a revolution (from the position shown) the magnetic flux through the armature core is again at or near its maximum value, but in the opposite direction from that at one-eighth of a revolution. At half a revolution there is no flux through the armature core. The same conditions exist again during the remaining half-revolution. There are, therefore, four electric impulses induced in the armature coils during each revolution of the inductor.

The beginning of the primary winding of the armature is connected to the frame of the magneto by the screw 7. The end of the primary winding is connected to the beginning of the secondary winding, and the junction of the two windings is connected to the insulated plate 8, which has electric connection to the insulated stationary contact-piece 9 of the interrupter. The stationary (insulated) contact-screw 10 of the interrupter is

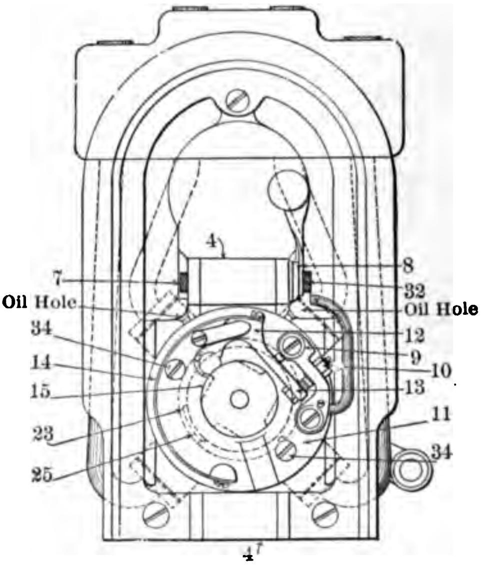


FIG. 246.

Interrupter End of Fig. 244 with some of the Parts Removed.

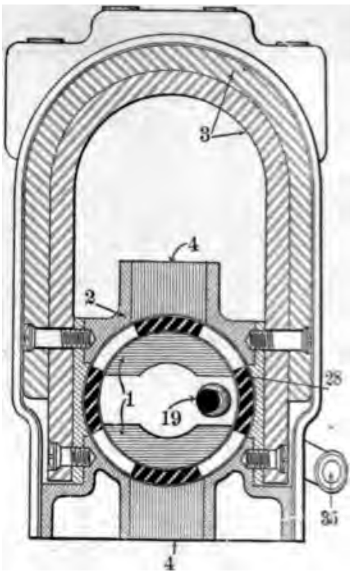


FIG. 247.

Cross-section of Fig. 244 on Plane *A-B* of Fig. 245.

carried by 9. The movable contact-screw 13 is in the end of the interrupter-lever 12. The flat spring 14 acts on lever 12 to press the contact-points together. The interrupter-lever is operated by a four-lobed cam 15 that is fastened to the inductor shaft and rotates with the inductor. The interrupter-lever is electrically connected to the frame of the magneto, so that when the contact-points of the interrupter are pressed together the primary circuit is closed. The cam forces the contacts apart four times each revolution of the inductor, thus interrupting the

primary current at each instant that it reaches its maximum value.

The interrupter is rigidly connected to the slotted tube, or shield, 28, and both are rocked together by means of the timing lever 35 to vary the instant of ignition. Rocking the tubular shield has the effect of moving the magnet-poles so as to always have the current at or near its maximum value at the instant of its interruption, as has been explained in the preceding section.

The high-tension terminal of the secondary winding of the armature is connected to the contact-piece 18, against which the insulated carbon brush 20 is pressed by a spring. The high-tension current flows from the brush 20 through the conductor 21 to the metal rotor 23 of the distributer. Conductor 21 is covered with insulation 19, and the metal rotor of the distributer is carried by the insulation 22. The stationary contact-pieces 25 of the distributer are connected by conductors 26 to the terminal block 27, from which wires lead to the spark-plugs.

Condenser 16 has one side connected to the junction of the primary and secondary windings, and the other side grounded to the body of the magneto. Terminal 29 is also connected to the junction of the primary and secondary windings. When this terminal is connected to ground, ignition is cut off on account of the primary circuit being thus permanently closed through a low-resistance path in parallel with the interrupter.

The rotative speed of the inductor, for a four-cycle motor with four combustion chambers, must be half that of the crank-shaft, which is the same as that of the cam-shaft, since there are four sparks produced during each revolution of the inductor.

A modified form of this magneto interrupts the current only twice during each revolution of the inductor, and therefore produces only two sparks per revolution of the magneto inductor. This modified form must rotate twice as fast as the one just described.

Of the numbered parts not mentioned, 17 is the condenser case, 24 the front plate of the magneto, 30 the rear housing, 31 the latch for holding the rear housing in place, and 32, 33, and 34 are screws for holding the removable parts in place.

191. Mea Magneto with Rocking Magnets. — This magneto has several distinctive features that are not found in those of

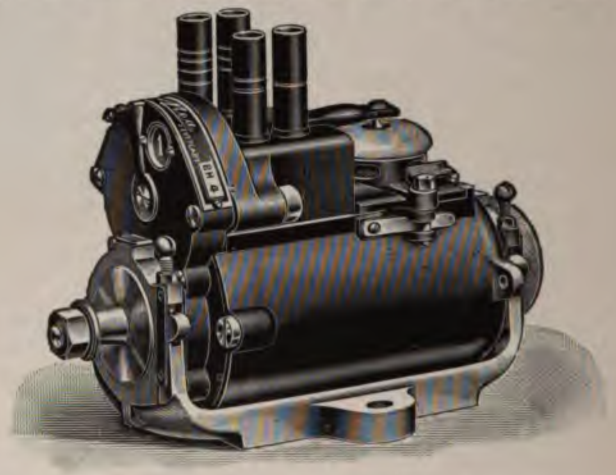


FIG. 248. (*See also* Figs. 249, 250, 251, 252, 253, 254, and Plates VI and VII.)
Mea High-tension Magneto Mounted on Trunnions. Marburg Bros., Broadway & 58th Street, New York City.

FIG. 249.
Bell-shaped Field-Magnets of Mea Magneto, Fig. 248.

earlier design. The principal unique feature is the use of parts of such a form that they can be assembled compactly so that the entire magneto can be rocked on a supporting frame, or base,

for advancing and retarding the ignition. The advance and retard can be carried to any extent ever required without affecting the strength of the ignition spark. The magnets and interrupter are of distinctive form, and there is a window through which the position of the distributer rotor can be observed.

Fig. 248 is a full view of the entire magneto resting on its supporting frame. The magnets are shown in Fig. 249 with the pole-pieces fastened to them. Fig. 250 is a longitudinal section of the magneto, and Fig. 251 is a full view of the interrupter end with the cover of the interrupter removed. Fig. 252 shows the working parts of the interrupter.

The magnets are called " bell-shaped " by the manufacturer. The armature is of the shuttle type with double winding. The armature shaft lies parallel with the length of the magnets, and one end of the shaft passes through a hole in the crown of the magnets. The armature does not differ essentially from those of the shuttle type ordinarily used.

The parts of the magneto are shown in detail in Plates VI and VII.

The wiring diagram is essentially the same as in Fig. 224. The beginning of the low-tension winding is grounded on the armature core. The end of the low-tension winding is connected to the beginning of the secondary winding of the armature, and the high-tension end of the secondary winding is connected to the insulated slip-ring, or collector-ring 4, against which the insulated carbon brush 77 bears. Current from the high-tension end of the winding passes through the brush 77, metal bridge 84, and brush 69 to the two brushes 68 of the distributer rotor. Each of these two distributer brushes distributes current to its own two of the four contact-pieces to which the terminals of the spark-plug wires are connected. The use of two brushes in the distributer rotor, as stated, makes it possible to have a rotor of small diameter without bringing the stationary contact-pieces of the distributer unduly close together.

The junction of the primary and secondary windings is connected to the insulated plate of the condenser 12. This plate

FIGS. 250, 251 and 252.

1. Armature.
4. Collector-ring, or slip-ring.
7. Pinion gear for driving the distributer rotor.
12. Condenser.

17, 18. Ball bearings.

24. Fastening and conducting screw.
27. Interrupter disk.
28. Insulated plate of interrupter.
30. Interrupter spring.
31. Fiber roller of interrupter.
33. Contact-point of interrupter.
34. Contact-point.
40. Cam-disk of interrupter.
46. Carbon brush.
47. Brush-holder.
50. Ground terminal.
53. Base of magneto.
66. Distributer rotor.
68. Brushes of distributer rotor.
69. Carbon brush bearing against distributer rotor.
70. Stationary plate of distributer, with contact-pieces.
72. Gear on distributer rotor.
74. Cover of interrupter housing.
76. Brush-holder.
77. Carbon brush on collector ring.
78. Brush making ground connection for armature.
84. Connecting bridge between 77 and the distributer rotor.
88. Arm for controlling the time of ignition.
91. Metal plate for supporting the brushes 77 and 78.
100. Magnets.
108. High-tension terminals.

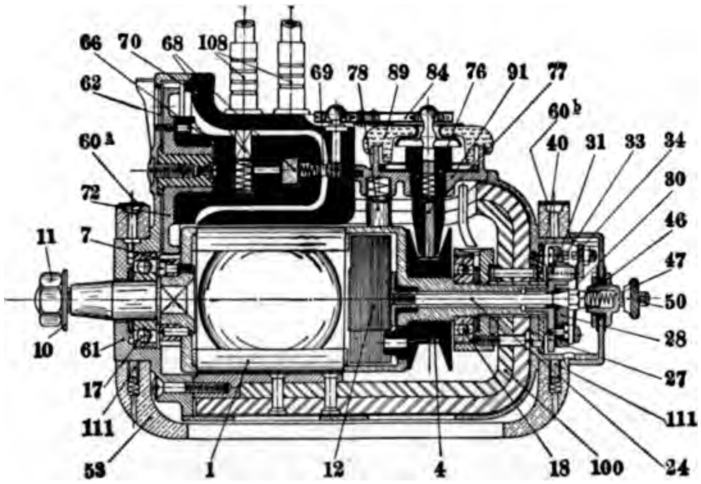


FIG. 250.
Longitudinal Section of Fig. 248.

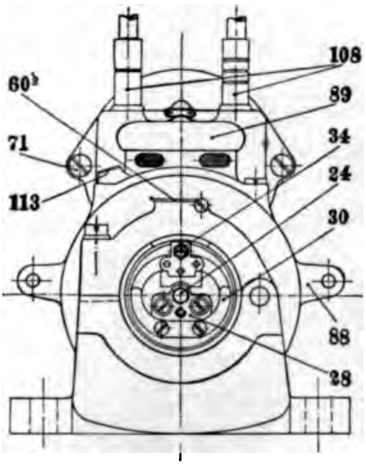


FIG. 251.
Interrupter End of Fig. 248 with Interrupter Cover removed.

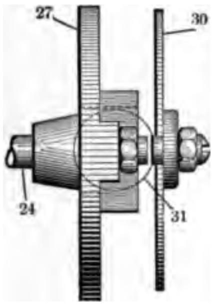


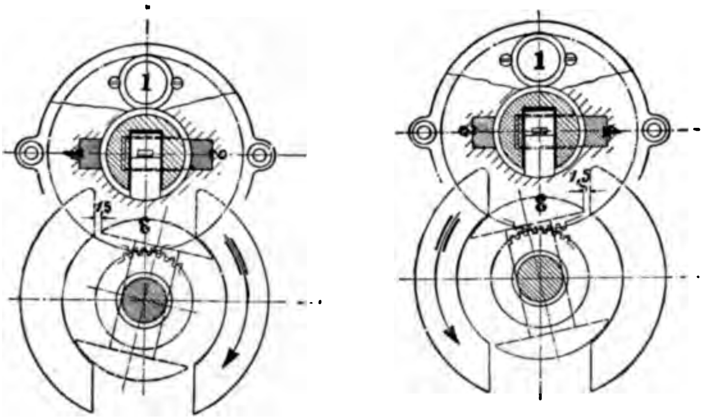
FIG. 252.
Interrupter of Fig. 248.

is threaded to receive the fastening screw 24 that holds the interrupter in place and conducts the primary current to its insulated block 28.

The interrupter spring 30, which carries the movable contact-point, is fastened to the insulated block 28. The interrupter spring has the general form of a thin washer that has been cut through on one side. The block 28 is fastened to the disk 27 but is insulated from it. The stationary contact-point of the interrupter is mounted on the disk 27, and both are electrically connected (grounded) to the frame of the magneto. The interrupter spring is forced back, in a direction approximately parallel to the length of the armature shaft, by the fiber roller 31 at the instant the primary circuit is to be broken. The roller is carried in a pocket in the disk 27. As the disk 27 and interrupter spring rotate with the armature, the roller strikes successively against two projecting lobes on the stationary cam-disk 40, and the roller is thus forced against the interrupter spring so as to push the latter back and separate the contact-points. The two lobes are half a revolution apart, so that the circuit is broken twice during each revolution. The parts of the interrupter are shown in Plate VI, Nos. 26 to 42 inclusive.

The numbers 1, 2, 3, 4 are marked on the gear-wheel which is attached to the distributer rotor of a magneto for four combustion chambers. This numbering is shown in Fig. 253. When the armature is in the position at which the interrupter contacts should just begin to separate, one of these numbers should register with a circular window in the upper part of the distributer casing. In Fig. 253 the numeral 1 registers with the window, and the armature is in the position, during its clockwise rotation, at which the interrupter contacts should begin to separate. When the armature has made half a revolution from this position, the numeral 2 will register with the window. The numbers can be seen, in the actual magneto, only when they register with the window. In the illustration, the lower part of the casing is broken away to show the numbers not at the window. The distance between the edge of the armature core and the edge of

the magnet-pole is given as 1.5 millimeters (about $\frac{1}{17}$ or .06 of an inch) in the figure. In Fig. 254 the corresponding positions of the armature and distributer are shown for counter-clockwise rotation of the armature.



FIGS. 253 and 254.

Relative Rotative Positions of Armature and Distributer in Fig. 248 for Right-hand and Left-hand Rotation.

There is a safety spark-gap for protecting the insulation of the magneto against excessive electric pressure in case one of the wires becomes disconnected from its spark-plug. The safety-gap cannot be seen in the illustration, however.

Plate VI.

1. Complete armature with condenser, small gear-wheel, slip-ring, and two ball-bearings without outer race collar.
2. Front armature-disk with spindle without other parts.
3. Rear armature-disk with spindle without other parts.
4. Slip-ring.
5. Front ball-bearing without race collar.
6. Rear ball-bearing without race collar.
7. Small gear-wheel.
8. Washer for slip-ring.
9. Fastening ring for 8.
10. Washer for spindle cone.
11. Nut for 10.
12. Complete condenser with brass furniture.
13. Silk strip for the circumference of the condenser.
14. Fastening screw of the condenser.
15. Silk insulating strip for the condenser.
16. Mica insulating plate for the condenser.
17. Complete front ball-bearing.
18. Complete rear ball-bearing.
19. Fastening screw for the small gear-wheel.
20. Fastening screw for the front armature-disk.
21. Fastening screw for the rear armature-disk.
22. Felt disk for the front ball-bearing.
23. Felt disk for the rear ball-bearing.
24. Fastening screw for contact-breaker.
25. Insulating piece for 24.
26. Complete contact-breaker.
27. Contact-breaker disk.
28. Contact-piece for contact-breaker spring.
29. Insulation for contact-piece.
30. Contact-breaker spring.
31. Contact-breaker roller.
32. Safety screw for 31.
33. Short platinum screw for contact-breaker.
34. Long platinum screw for contact-breaker.
35. Fastening screw for contact-piece 28.
36. Vulcanite insulation for 35.
37. Fastening screw for contact-breaker spring.
38. Washer for 37.
39. Insulation bush for contact-breaker disk.
40. Stud ring.
41. Fastening screw for stud ring.
42. Safety pin for stud ring.
43. Case for rear ball-bearing complete with race collar and fastening screw.
44. Race collar of rear ball-bearing.
45. Fastening screw for ball-bearing case.
46. Carbon brush for cover of contact-breaker case.
47. Complete fastening for 46 with nut.
48. Body for 47.
49. Fastening screw for 48.
50. Nut for switch wire (short circuit).
51. Mica disks for 48.

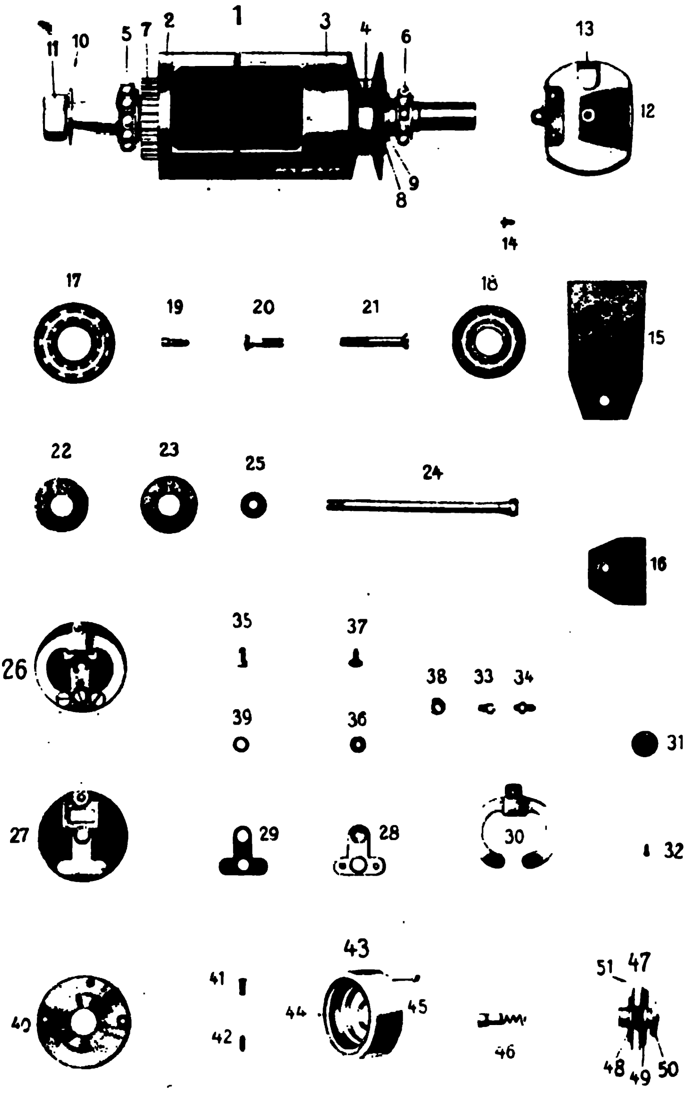


PLATE VI.
Parts of Fig. 248.

PLATE VII.

52. High-tension cable with terminal and cable sleeve.
53. Complete base for magneto.
54. Hinged link for closure of the base bearing.
55. Tension screw for 54.
56. Joint nut for 55.
57. Counter nut for 56.
58. Cover of the rear base bearing.
59. Cover of the front base bearing.
60. Oil cover for 58 or 59.
61. Side bearing cover.
62. Mica cover for inspection opening.
63. Ring around opening.
64. Fastening screw for 63.
65. Fastening screw of side bearing-cover.
66. Distributer finger.
67. Fastening screw for distributer finger.
68. Radial distributer carbon with spring.
69. Axial distributer carbon with spring.
70. Distributer case.
71. Fastening screw with nut for distributer case.
72. Large gear-wheel.
73. Case for contact-breaker.
74. Cover for 73.
75. Screw for 74.
76. Carbon holder.
77. Carbon with spring for 76.
78. Carbon with spring for body contact-screw.
79. Shaft of the distributer complete.
80. Spindle for distributer gear-wheel.
81. Fastening screw for 80.
82. Disk with safety pin.
83. Fastening screw for 82.
84. Connection piece between carbon holder and distributer.
85. Magneto casing complete without cover.
86. Spring of the closure.
87. Fastening screw for 86.
88. Timing lever.
89. Cover for magneto casing complete.
90. Spring for oil-hole.
91. Fastening screw for 90.
92. Catch-bolt with nut for cover of the magneto casing.

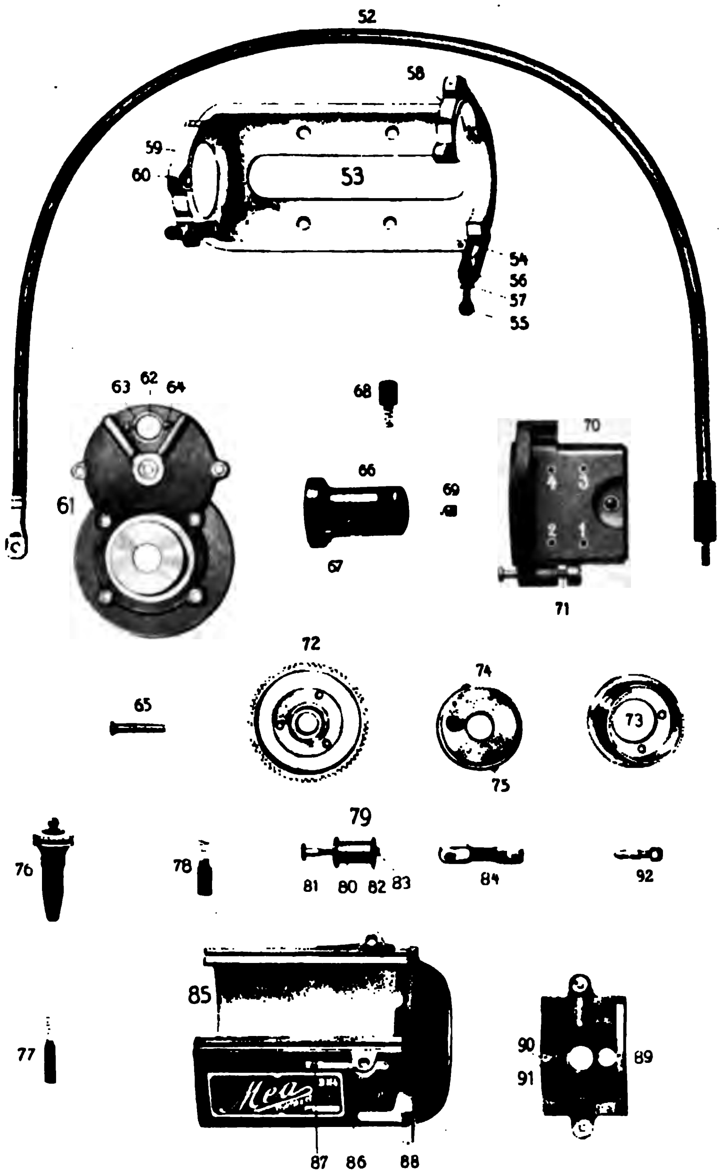


PLATE VII.
Parts of Fig. 248.

CHAPTER XXI.

HIGH-TENSION DUAL AND COMBINED IGNITION SYSTEMS.

192. Introductory. — Of the ignition diagrams in this chapter those which give the electric connections in detail are either in accordance with blue prints and drawings kindly furnished by the manufacturers or their agents, or are diagrams made by the Author and approved by the manufacturers or their agents. The illustrations showing the general external appearance of the ignition systems are generally taken from the trade literature of those who make and sell ignition apparatus or put it into use.

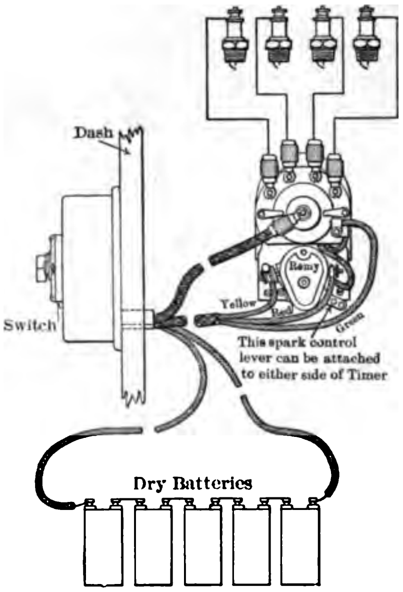


Fig. 255. (*See also* Fig. 256.)
Remy High-tension Ignition System.

Most of the detail diagrams from manufacturers and agents have been modified slightly in unimportant details in order to make them conform more nearly with the conventions used throughout this book.

Some of the systems represented are early ones that were much used at one time, but have been improved upon by the manufacturers, and in some cases almost or quite discarded by them so far as new installations are concerned. It is believed, however, that these earlier systems deserve description on account of the importance they once had and because many of them are still in use where they were installed in earlier constructions.

193. Remy Ignition System with Separate Transformer. — The Remy magneto has been described in another chapter. The general outside appearance of the ignition system used with this magneto is shown in Fig. 255. A non-trembler transformer spark-coil with its own condenser is used in connection with both the magneto and a battery. A turn-switch and a push-button are mounted on the box which contains the transformer and the

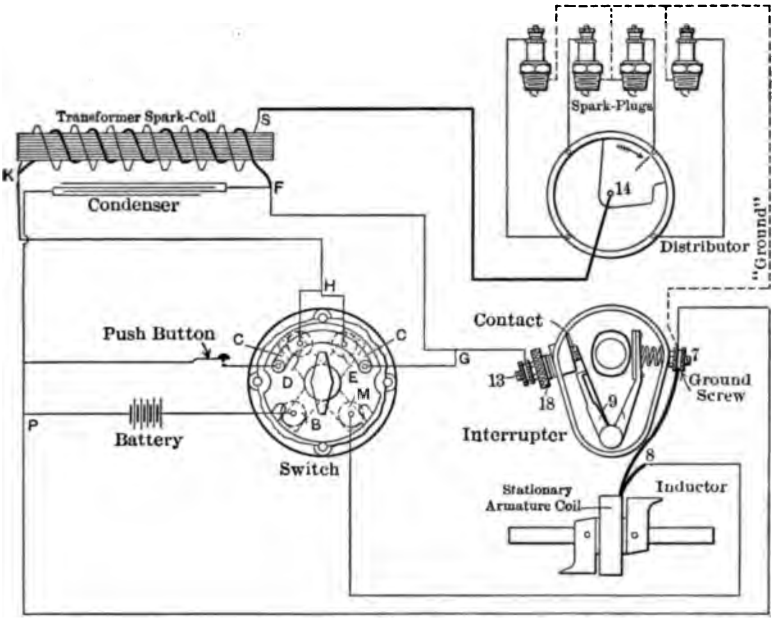


FIG. 256. (*See also* Fig. 255.)
Internal and External Connections for Remy High-tension Ignition System.

condenser. The battery is for starting the motor on " spark " by pushing and releasing the push-button when the switch is set in the battery position.

The wiring connections are shown in detail in Fig. 256. The insulated terminal 8 of the stationary armature of the magneto is connected to the contact-point, or pole, *M* (represented by a dotted circle), of the switch. The other terminal of the armature winding is connected to the ground-screw 7 of the magneto. The ground-screw is connected by a wire to one side each of the

battery, the push-button, and the condenser. The insulated terminal 13 of the magneto interrupter is connected to the low-tension terminal *F* of the transformer, which is also connected to one side of the condenser. The insulated terminal 13 is also connected to a crescent-shaped piece of metal *C–C* in the switch. *C–C* is not connected to any of the contact-points, or poles, of the switch, but is connected to one of the contacts of the push-button. One side of the battery is connected to the pole *B* of the switch. The junction *K* of the two windings of the transformer is connected to both of the poles *D* and *E* of the switch. The high-tension terminal *S* of the transformer is connected to the rotor 14 of the distributer. The cross-bar of the switch is not shown in its position corresponding to that in which the diamond-shaped switch-handle is represented. It is shown by broken lines in two positions. In one of these positions, when connecting *M* and *D*, the magneto is cut into circuit so that its current is used and the battery is out of circuit. In the other position of the switch-bar, when connecting the poles *B* and *E*, the battery is in circuit and the armature of the magneto is cut out. The interrupter of the magneto is always kept in circuit, since it must interrupt the current whether it comes from the battery or the armature of the magneto. The condenser is in parallel with both the interrupter of the magneto and the push-button.

When the switch is set to use magneto current, the path of the primary current, assuming a direction of flow, is from the insulated terminal 8 of the armature winding to switch-pole *M* through the switch-bar from *M* to *D*, thence to *H* and on to the junction terminal *K* of the transformer, through the transformer primary to *F* and on to the insulated terminal 13, which carries it to the contact-points of the interrupter, from which it goes through the interrupter lever 9 to the ground-screw 7 to which the other end of the armature winding is connected. Since the primary current is an alternating one, it of course flows in this direction at one impulse and in the opposite direction at the next impulse.

The secondary current flows from the high-tension terminal *S*

of the transformer to the rotor 14 of the distributer, and the rotor directs it to the spark-plugs. From the spark-plugs the high-tension current goes through ground to the ground-screw 7, then through the armature winding to 8 and on through the connecting wire to the switch-pole *M*, through the switch-bar to *D*, thence to *H* and the junction terminal *K* of the transformer. It is probable that some of the high-tension current does not go through the armature winding as just stated, but goes from the ground-screw 7 through the interrupter, jumping the space which exists at the instant between the contact-points of the interrupter, so as to reach the insulated terminal 13, then flows through the connecting wire to *F* and on through the primary of the transformer to the junction point *K*, thus completing the circuit when the secondary of the transformer is included. The high-tension current of course also alternates in its direction of flow in the same manner that the primary current does while the system is operating on magneto current. The battery circuit is open at the switch when the magneto is cut into circuit, since under this condition the pole *B* of the switch has no connection with anything but one side of the battery.

When the switch is set to the battery position, the poles *B* and *E* are connected, and the magneto circuit is left open at the pole *M*. The path of the battery current is then from *B*, through the switch-bar to *E*, thence to *H* and on to the junction terminal *K* of the transformer, through the transformer primary to *F* and on through the connecting wire to the insulated interrupter terminal 13, then through the interrupter to the ground-screw 7 and on through the connecting wire to *P* and the battery. The path of the high-tension current is from the secondary high-tension terminal *S* to the distributer, the spark-plugs and ground in series as before to the ground-screw 7, but from 7 it goes through the connecting wire to *P*, thence through the battery and switch to *B* and *E*, then to *H* and the junction terminal *K* of the transformer. Just as in the case of using magneto current, part of the secondary current may go from 7 through the interrupter to the primary terminal of the transformer.

If the push-button contacts are pressed together while the switch is set in battery position and the contacts of the magneto interrupter are separated, then current will flow from the battery to the switch-pole *B*, switch-bar to *E*, then to *H* and on to the junction terminal *K*, through the primary winding of the transformer to *F*, thence to *G* and on to the crescent-shaped bar *C–C*, to and through the push-button and on to *P* and the battery. If the push-button contacts are then allowed to spring apart quickly, the interruption of the battery current will cause a spark to jump at one of the spark-plugs. In this manner a motor can be started on spark when there is a combustible charge in the combustion chamber at whose spark-plug the spark jumps. The condenser, being in parallel with the push-button, aids in the production of a jump-spark in the same manner that it aids the interrupter when the latter is operating.

FIG. 257.
Single-wound Magneto with High-tension Distributer. C. F. Splitdorf, New York City.

The push-button can also be used to cut out ignition when the motor is running on either battery current or magneto current. This is done by keeping the contacts of the push-button pressed together. As long as the contacts of the push-button are kept pressed together there is a permanently closed circuit, through which either the battery current or the magneto current, according to the setting of the switch, can flow without going through the interrupter. The latter cannot, therefore, interrupt the current so as to produce an ignition spark as long as the push-button circuit is kept closed.

194. Splitdorf Ignition System with Separate Transformer. — The magneto used in this system is shown in Fig. 257. It has a rotary armature of the shuttle type with one winding, and is provided with a mechanically operated interrupter and a high-

tension distributer. The interrupter and distributer end of an earlier type of the magneto is shown in Fig. 258. This earlier type is shown because it conforms to the wiring diagram of Fig. 259, which gives the external appearance of the connections. This wiring diagram is essentially the same as that for the later form of the magneto.

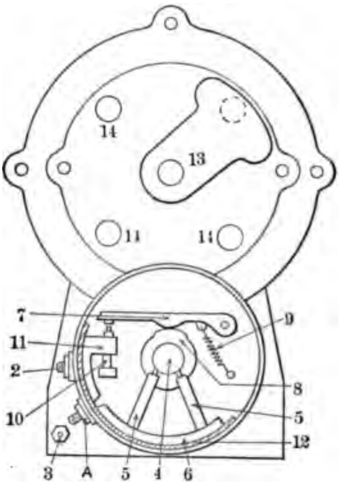


FIG. 258.

Interrupter End of Early Form of Splitdorf Magneto. Cover Removed.

A. Insulated outside terminal of armature winding. Connected to brushes 5, 5.
2. Insulated terminal connected to contact-screw 10.
3. Ground terminal for connecting to outside wires.
4. Insulated central rod or screw connected to insulated end of armature coil.
5, 5. Brushes pressing against 4.
6. Insulated brush-holder for 5, 5. Connected to A.
7. Interrupter arm, or lever. Grounded.
8. Cam for lifting interrupter arm. Grounded.
9. Tension spring for holding interrupter arm against cam and contact-screw.
10. Contact-screw. Insulated and stationary.
11. Bracket for holding contact-screw.
12. Insulation.
13. Distributer rotor. High-tension.
14. Contact-points of terminals for wires leading to spark-plugs.

The electrical connections are shown in detail in Fig. 260.

The magneto operates on the interrupted short-circuit principle while using its own current. An elementary system of this

nature has been shown in Fig. 223. When the battery is in use, the interrupter of the magneto breaks the battery circuit completely at the instant of ignition.

In the magneto, one end of the armature winding is grounded to the armature core and consequently to the frame of the machine. A ground terminal 3 is provided for making connection to an external wire. The insulated end of the armature winding is connected to an insulated rod, or long screw, 4, which passes through the hollow spindle of the armature and projects beyond the end of the spindle. Two insulated brushes, 5, 5, (which

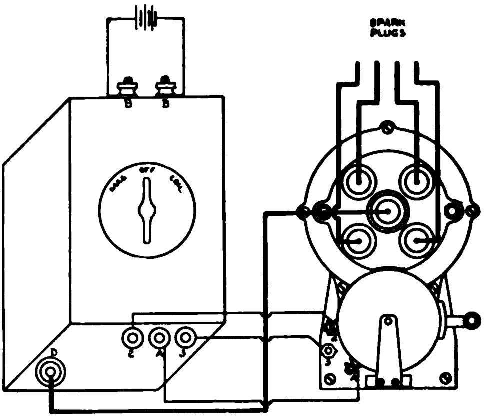


FIG. 259. (*See also* Fig. 260.)
Splitdorf High-tension Ignition System.

are replaced by a single brush that bears against the end of screw 4 in the more recent design) press against the cylindrical surface of 4 near its outer end. These brushes are carried in the brush-holder 6 which is electrically connected to the terminal *A*. The stationary contact-screw 10 is carried by the insulated bracket 11 which has the terminal 2. The interrupter-lever 7 is pivoted at its right-hand end and held against the cam 8 by the tension spring 9. The cam is mounted on the tubular portion of the armature shaft. The interrupter-lever is grounded to the frame of the magneto.

When the switch-blade is set in the magneto position, as in Fig. 260, the battery is cut out of circuit. The primary current flows from the insulated terminal *A* of the magneto to the point *B* of the switch. When the contact-points of the interrupter 7–10 are separated, as shown, all of the armature current flows from *B* on through the switch-blade to its pivot *E* and then through the permanent connection from *E* to *F*. From *F* the current flows to and through the primary winding of the transformer spark-coil, then from the junction of the two windings of

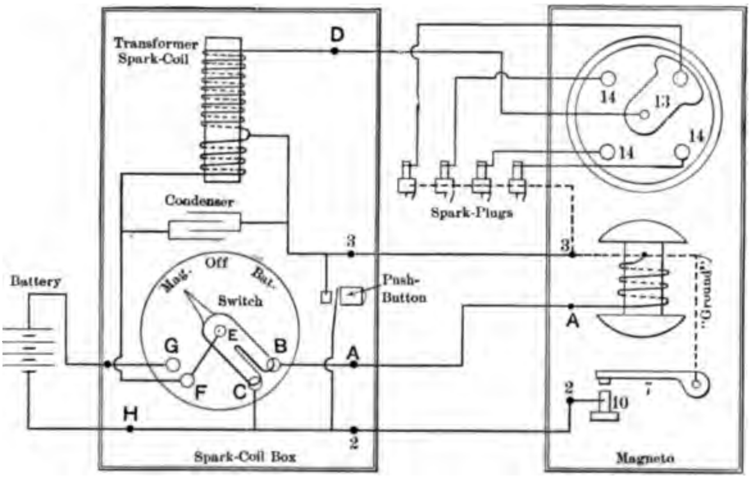


FIG. 260. (*See also* Fig. 259.)

Internal and External Connections for Splitdorf High-tension Ignition System.

the latter back to the ground terminal 3 of the magneto, which brings it to the armature winding again. But while the contact-points of the interrupter are together so as to close the circuit through the interrupter, the current divides at the switch-blade, most of it going to the switch-point *C* and then by the path 2–2 to the insulated contact-point 10 of the interrupter, and thence through the interrupter-lever to ground and the grounded end of the armature winding. The resistance of the shunt-circuit *C*–2–2–10–7 through the closed interrupter is very much less than that of the circuit through the spark-coil, therefore most of the

armature current flows through the shunt circuit while the interrupter is closed. When the interrupter breaks the shunt circuit, at the instant the armature current is at or near its maximum value, sufficient current is sent through the spark-coil primary to cause a spark to pass at the spark-plugs.

The high-tension current, after flowing from the secondary terminal *D* to the distributer and one of the spark-plugs in the usual manner, can return to the spark-coil through the permanently closed circuit 3–3. Part of it may go back by way of the armature and part through the interrupter, however.

When the switch is set in battery position, with the finger on the blade pointing to "*BAT*," the armature circuit of the magneto is left open at *B*. Battery current then flows to the switch-point *G*, on through the switch-blade to *F*, and thence through the primary of the spark-coil and the connections to the ground terminal 3 of the magneto. This brings it to the grounded interrupter lever 7, from which it flows through the contact-points of the interrupter to 10, and thence through the connections 2–2–*H* to the battery. The battery circuit is broken by the interrupter at the instant ignition is to occur, as has been stated.

The push-button can be used for starting the motor on spark with battery current, or for cutting out the ignition when the motor is running on either battery current or magneto current. Closing the push-button and then allowing its contacts to separate quickly, when the switch is in battery position and the interrupter contacts open, produces an ignition spark at one of the plugs. Keeping the push-button closed makes a permanent circuit in parallel with the interrupter, such that the action of the latter when the motor is running will not cause an ignition spark.

195. Eisemann Ignition System with Separate Transformer.—The external connections of this system are shown in Fig. 261, and the complete wiring system is shown conventionally in Fig. 262. The magneto has an armature of the shuttle type with a single winding and operates on the interrupted shunt-circuit system. The spark-coil is of the non-trembler transformer type. A battery is provided.

The switch-handle 1 is shown in its position for cutting off ignition, and the switch-plug which goes in the hole 2 is removed. In order to throw in either the battery or the magneto, the plug must be inserted at 2 and the switch-handle thrown either to the left or right, according to whether the magneto or the battery is

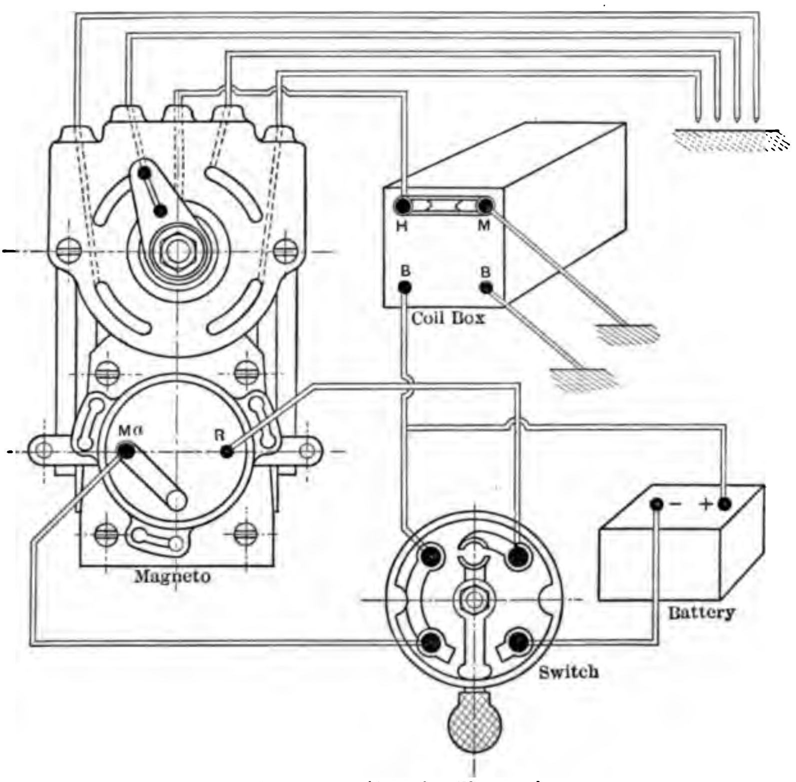


FIG. 261. (*See also* Fig. 262.)

Eisemann High-tension Ignition System, Early Form. Eisemann-Magneto Company, New York, N. Y., and Detroit, Michigan.

to be put into operation. The handle of the switch is hinged at the center of the large circle. The arm which extends from the center of the large circle up to 2 does not swing with the handle, but remains permanently in the position shown.

When the magneto is cut into circuit by putting the plug into the hole at 2 and throwing the switch to the left so as to make

connection between the contact-pieces 3 and 4, referring more particularly to Fig. 262, the current from the magneto terminal *Ma* flows through the connecting wire to the switch-point 4 and switch-blade 1. The current divides at the switch-blade when the interrupter 7–8 of the magneto has its contact-points together

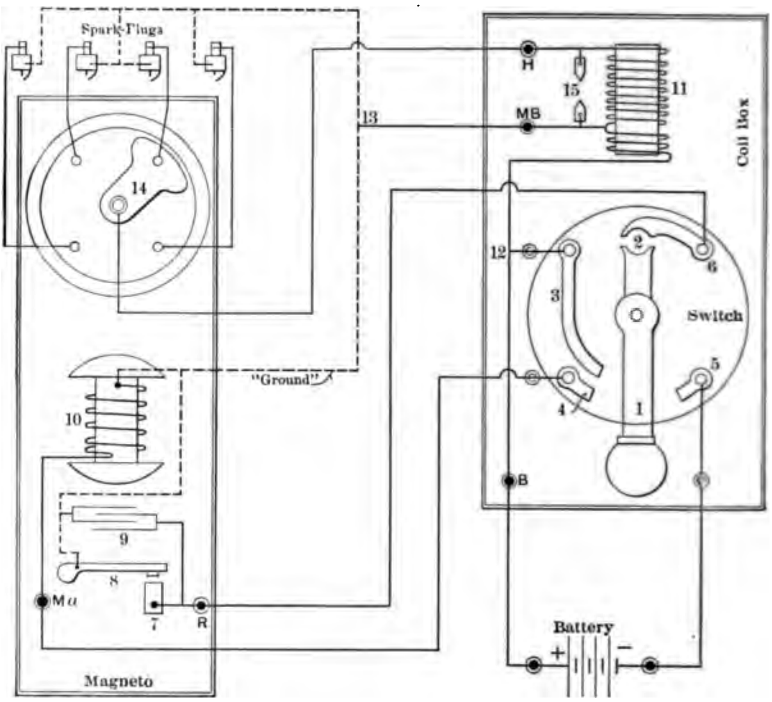


FIG. 262. (*See also* Fig. 261.)

Internal and External Connections of Early Form of Eisemann High-tension Ignition System.

so as to close its circuit. Most of the current then flows through the low-resistance shunt circuit from 1 to the plug in 2, then to 6 and on through the connecting wire to the stationary contact-point 7 of the interrupter and to the interrupter-lever 8, which brings it to the grounded end of the armature winding 10. A small portion of the current flows from 1 to the switch-point 3 and on to 12 and the primary winding of the spark-coil 11, then

from the junction of the two windings of the coil to the terminal *MB* and on to ground at 13, thus returning to the ground end of the armature winding of the magneto. At the instant that the interrupter breaks the shunt circuit by separating the contact-points 7 and 8, a comparatively large current is sent through the primary of the spark-coil and a jump-spark passes between the points of one of the spark-plugs. The high-tension terminal *H* of the spark-coil is connected to the rotor 14 of the distributer, which is of the usual form.

When the battery is in circuit, the switch-blade being thrown to the right to make contact with the switch-point 5, and the plug in at 2, the magneto armature is on open circuit. Current flows from the positive (+) side of the battery through the connection *B*–12 to the primary winding of the spark-coil and thence through *MB* to ground at 13. This brings it to the interrupter lever 8, from which it passes through the closed contact-points to the stationary contact-piece 7 and thence through *R* to the switch terminal 6, then through the plug in 2 and on through the switch-blade 1, which is in contact with 5, and on to the negative (−) side of the battery. Interruption of the current by the separation of the contact-points of the interrupter produces a spark at one of the spark-plugs.

The condenser 9 is in parallel with the interrupter in the usual manner. A safety spark-gap is shown at 15.

196. Eisemann-Carpentier Ignition System. — Figs. 263 and 264. In this system the battery has its own timer and trembler spark-coil, and the magneto has its own mechanically operated interrupter and a non-trembler spark-coil. The same distributer is always used for directing the high-tension current to the spark-plugs. The two spark-coils are inclosed in the same box, which has a hand-switch for throwing in either the battery or the magneto, or for cutting both out of circuit.

The movable part of the switch is represented conventionally, in Fig. 264, as a piece of insulating material 1 to whose ends are fastened two metal contact-pieces 2 and 3. The stationary contact-points of the switch are 4 and 5 for the battery circuit, 6 and 7 for the magneto circuit, and 8, 9, and 10 for the high-

tension circuits. The timer is of the form common to battery ignition systems with individual spark-coils of the trembler type, but is modified by connecting all of the stationary contact-points together with a wire 16.

The switch is shown set for using battery current. The path of the current is from the positive (+) side of the battery to the terminal *P* and switch-pole 4, through 2 to 5, thence to the trembler interrupter 11 and primary winding of transformer 17, from which it flows to ground by the path 12–13–14. This brings it to the rotor 15 of the timer, from which it goes to the

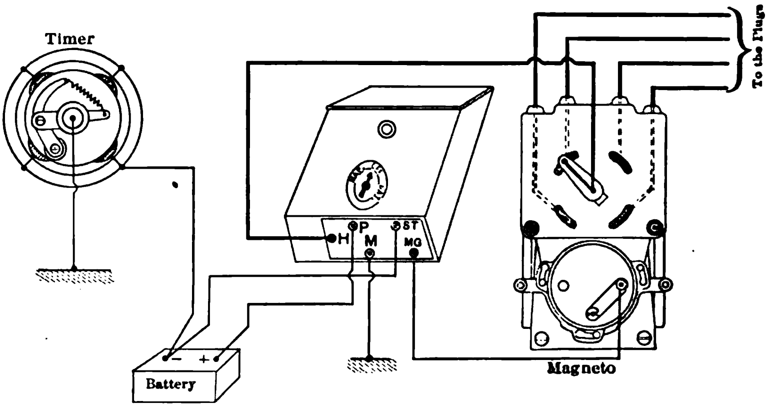


FIG. 263. (*See also* Fig. 264.)
Eiscmann-Carpentier High-tension Ignition System.

negative (−) side of the battery. The high-tension current follows the path from the secondary terminal 19 to the switch-pole 8, then through 3 to switch-pole 9, thence to terminal *H* and on to the rotor 21 of the distributer, which directs it to the spark-plugs. From the ground side of the spark-plug the high-tension current has the permanent circuit 14–13–12 back to the spark-coil 17.

When the switch is set to the position for magneto current, the part 2 connects the poles 6 and 7, and the part 3 connects poles 9 and 10. The magneto is of the interrupted shunt-circuit type. During the time the interrupter parts 23 and 24 are in

contact with each other (interrupter closed) most of the armature current flows from 23 through the interrupter lever 24 to ground and thence to the grounded end of the armature winding 25. A small portion of the armature current flows at the same time from 23 through the path 22–*MG* to the switch-pole 7, then

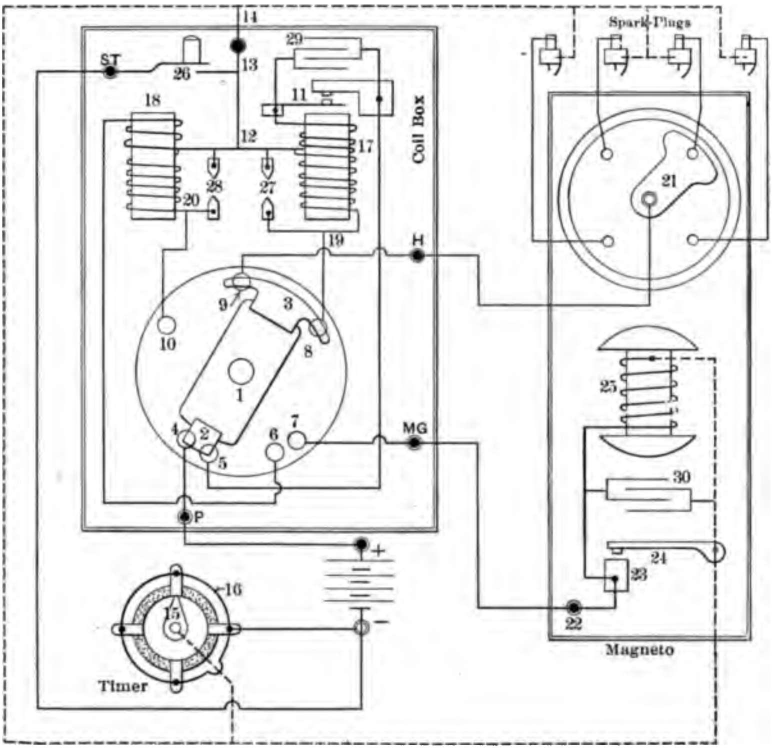


FIG. 264. (*See also* Fig. 263.)

Internal and External Connections of Eisemann-Carpentier High-tension Ignition System.

through 2 to 6 and on to the non-trembler transformer 18, through whose primary winding it flows, and then to ground by the path 12–13–14. This brings it to the grounded end of the armature winding. At the instant the shunt circuit is broken by the interrupter of the magneto, a comparatively large current is sent through the transformer circuit just followed out, and

a spark is caused to jump at one of the spark-plugs. The high-tension current goes from the secondary terminal 20 to switch-pole 10, then through the metal 3 on the switch-bar to pole 9 and on to the rotor 21 of the distributer.

The push-button 26 is for starting the motor on spark. The switch must be set in battery position, as shown, when doing this, and the timer rotor must not be in contact with any of the stationary contacts of the timer. Pressing the push-button then closes the battery circuit through the trembler coil 17. If the rotor of the timer is in contact with one of the stationary contact-pieces of the timer while the motor is standing still, the battery circuit is then closed through the trembler coil when the switch is in the position shown.

The safety spark-gap 27 is for protecting the trembler coil 17, and the safety-gap 28 answers the same purpose for coil 18.

The condenser 29 is in parallel with the trembler interrupter 11, and condenser 30 is in parallel with the interrupter 23–24 of the magneto.

The rotor of the timer and the interrupter of the magneto must be set so that the instant of ignition will not be greatly changed by switching from one source of primary current to the other.

197. Bosch Dual Ignition System. — Fig. 265. This system operates on magneto current or on battery current, according to the position of the switch. It comprises a high-tension magneto having two interrupters and a double-wound armature of the rotary shuttle type, a transformer spark-coil in conjunction with a switch, a battery, and jump-spark igniters as its chief elements. Of the two mechanically operated interrupters in the magneto, one is for the battery current and the other for magneto primary current. The transformer coil is not in action while the system is operating on magneto current.

The transformer is of the non-trembler type, so far as its operation while the motor is running is concerned, but it has a trembler interrupter to be used for starting the motor on spark. When the switch is in battery position, pressing the push-button lightly closes the battery circuit at the trembler inter-

rupter, and the trembler then begins to vibrate so as to interrupt the battery current through the spark-coil, provided the magneto has not stopped in such a position as to keep the battery circuit closed on account of its interrupter contacts being pressed together. But if the battery circuit is closed in the magneto, as just stated, then a harder pressure on the push-button, followed immediately by release of pressure, produces a spark at the igniter at the instant of release of pressure.

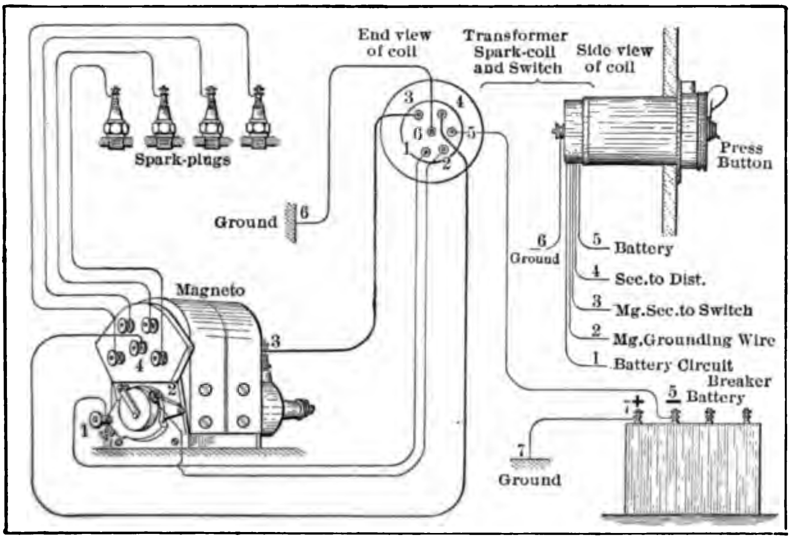


FIG. 265. (*See also* Figs. 266, 267, and 268.)

Bosch Dual High-tension Ignition System.

The interrupter end of the magneto is shown in Fig. 266. In this figure, the interrupter for the current generated in the primary winding of the magneto is called the "magneto interrupter," and that for interrupting the battery current is called the "battery timer." Both of these are of the rocking-lever type.

The magneto interrupter rotates with the magneto armature. A piece of fiber in one end of the lever strikes against cam-lobes so that a rocking movement of the lever is produced twice

during each revolution of the armature. The upper end of the lever, as shown in the illustration, is in contact with one of the cam-lobes. The part to which these cam-lobes are attached does not rotate, but can be rocked by the spark control to vary the time of ignition. The contact-piece which carries the "interrupter adjustment" is connected to the junction of the primary

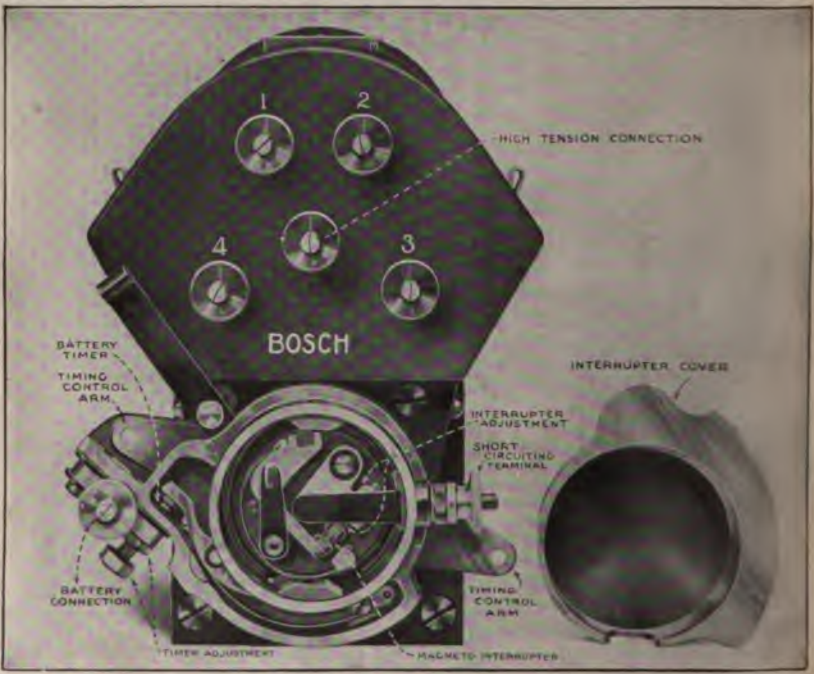


FIG. 266.

High-tension Magneto with Two Interrupters for Fig. 265.

and secondary windings of the armature and to the insulated "short-circuiting terminal," but is insulated from the other parts of the magneto. The interrupter-lever of the magneto interrupter is electrically connected to the frame of the magneto.

The battery timer does not rotate. Its interrupter-lever is operated by a two-lobed steel cam which revolves with the armature of the magneto. This cam is in the form of a steel ring with outwardly projecting lobes. The interrupter-lever of

the battery timer is electrically connected to the frame of the magneto. The " timer adjustment " and the " battery connection " are electrically connected together and are insulated from the other parts of the magneto. The battery timer moves with the " timing control arm " when the latter is rocked to vary the time of ignition.

The " high-tension connection " is in permanent electric connection with the distributer brush.

The beginning of the primary winding of the armature is electrically connected to the armature core and thence to the

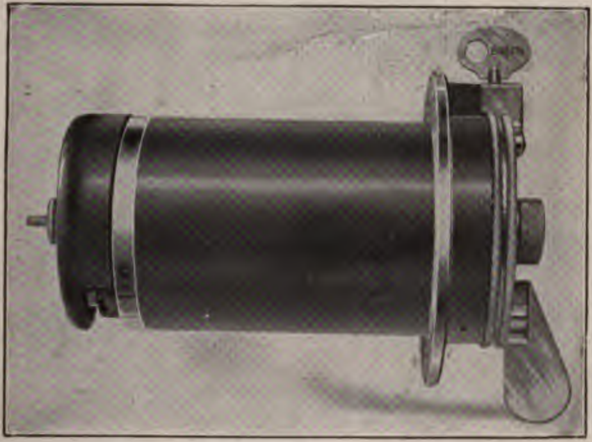


FIG. 267. (*See also* Fig. 268.)
Transformer Spark-Coil and Switch for Fig. 265.

frame of the magneto; the high-tension end of the secondary winding is connected to a slip-ring against which bears a brush that is carried by the insulated brush-holder 3, Fig. 265. There is no connection, in the magneto, between the high-tension winding of the armature and the distributer. It has been stated that the junction of the two armature windings is connected to the insulated part of the magneto interrupter.

The combined spark-coil, switch, and push-button starter are shown assembled in Fig. 267. The coil body, the connecting plate of the switch, and the protecting cover for it are shown

separately in Fig. 268. The switch is provided with a lock and removable key, by means of which it can be locked so that the ignition system cannot be used.

When the switch is in battery position, the battery circuit is closed at the coil, and the high-tension terminal of the transformer coil is connected to the central terminal 4 of the distributer of the magneto. The short-circuiting terminal 2 of the magneto is also connected to ground through the switch so as

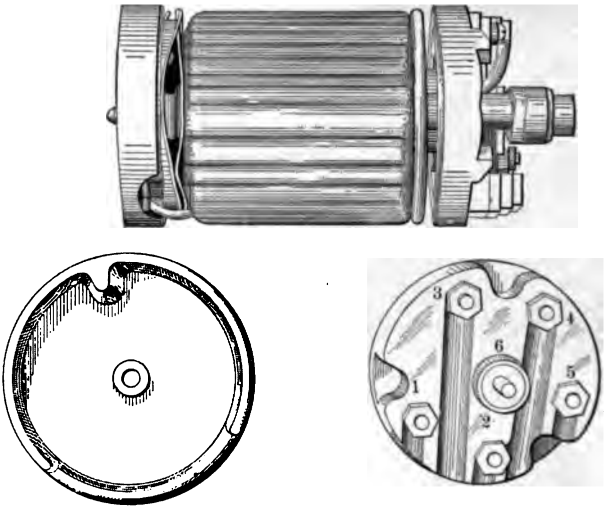


FIG. 268.

Parts of Fig. 267.

to prevent the induction of high pressure in the magneto armature, and the high-tension terminal 3 of the magneto is on open circuit at the switch. Under this condition the magneto is electrically inactive, although its parts move mechanically in the usual manner. The battery timer interrupts the battery current, which flows through the primary winding of the spark-coil, thus inducing high-tension current in the secondary of the spark-coil, which current flows to the distributer brush of the magneto and is distributed to the spark-plugs.

When the switch is in magneto position, the battery circuit and the high-tension circuit of the spark-coil are both open at

the switch, thus making the battery circuit inoperative. The short-circuiting circuit is open at the switch, and the high-tension terminal 3 of the magneto is connected, through the switch, to the distributer terminal 4 of the magneto. The magneto then generates and delivers high-tension current to the spark-plugs. The battery timer is electrically inoperative under this condition, but moves mechanically in the usual manner.

197.1. Duplex High-tension Ignition System Having a Battery in Series with the Primary Winding of the Magneto. — The complete system is shown in Fig. 269. Its essential parts

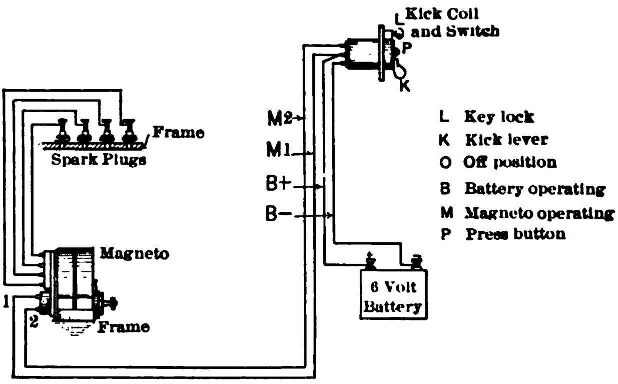


FIG. 269. (*See also* Figs. 270, 271, and 272.)
Bosch Duplex High-tension Ignition System.

are the spark-plugs; a battery; a combined kick-coil, switch, and push-button; and a magneto of the double-wound shuttle-armature type provided with a two-segment commutator and commutator brushes in addition to the mechanically operated interrupter. The connections between the magneto, the battery, and the kick-coil are shown more distinctly in Fig. 270. The kick-coil, Fig. 271, has only one winding, and is provided with a key lock for preventing the use of the ignition system while the coil is locked. The interrupter end of the magneto is shown in Fig. 272.

The switch can be set for operating the magneto system on both battery and magneto current, at the same instant, and for

operating on magneto current only. The real purpose of the battery is to supply current for starting the motor, either on spark by using the push-button, or when cranking the motor or otherwise driving it by power from some external source.

Referring to the magneto, Fig. 272, the beginning of the primary winding of the shuttle-wound armature is grounded to the armature core. The junction of the two windings is connected to the insulated side of the interrupter. This side of the

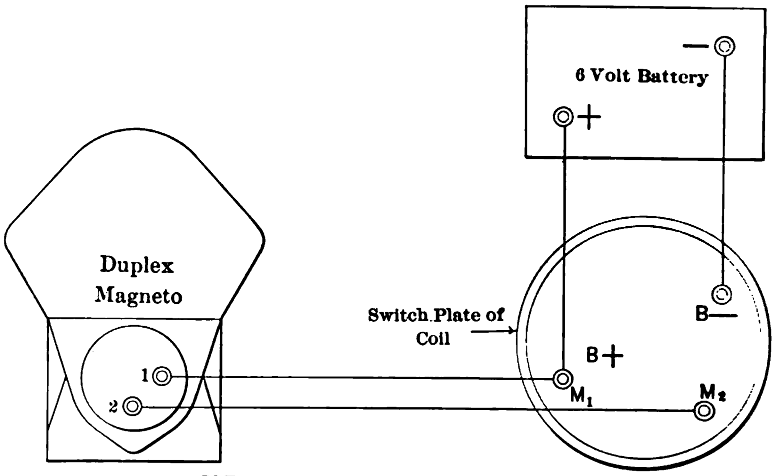


FIG. 270.

Low-tension Connections for Bosch Duplex Ignition System.

interrupter has the means of adjustment for one of the platinum contact-points. The high-tension end of the secondary winding is connected to the distributer brush by means of a slip-ring, brushes, and other suitable connectors, or other corresponding devices. The interrupter-lever is grounded to the frame of the magneto.

The characteristic feature of this magneto consists of a two-segment commutator whose insulated segments are fastened to the inner side of the interrupter cover, and a pair of carbon brushes, *A* and *B*, which make sliding contact with the commutator.

Brush *A* is carried by and electrically connected to the insulated side of the interrupter, and brush *B* is electrically connected to the grounded lever of the interrupter. Each commutator segment has an insulated terminal connected to it. These two terminals are on the outer side of the interrupter cover. They are numbered 1 and 2 in Figs. 269 and 270.

When the switch is set in its battery-magneto position, one side of the battery is connected to terminal 1 of the commutator, and the other side of the battery is connected to terminal 2 of

FIG. 271.
Single-wound Kick-Coil for Fig. 269.

the commutator. As shown in Fig. 270, the positive (+) side of the battery is permanently connected to terminal 1 of the commutator, and, when the switch is in battery-magneto position, the negative (−) side of the battery is connected to terminal 2 of the commutator. Then, while the armature is standing still with brush *A* in contact with the commutator segment to which terminal 1 is connected, and carbon brush *B* in contact with the commutator segment connected to terminal 2, current flows from the positive side of the battery to brush *A*, thence in parallel through the interrupter contacts and the primary of the

armature in parallel while the interrupter contacts are together, or through the primary of the armature alone while the interrupter contacts are separated, to brush *B* and the commutator segment connected to terminal 2, and on back through the switch to the negative side of the battery. The current thus flows into the insulated end of the primary of the armature and out of the grounded end of the primary, while the conditions are as just described. The ohmic resistance of the kick-coil limits the battery current to a safe amount. When the armature and the interrupter have been rotated to a position to bring the brush *B* into contact with the segment connected to terminal 1, and brush *A* into contact with the segment connected to terminal 2, then, while the armature is at rest, the battery current flows through the armature primary in the opposite direction. By quickly separating the closed contacts of the interrupter while battery current is flowing through them, the consequent interruption of the battery current sends a sudden impulse of battery current through the primary of the armature so as to induce an electromotive force in the secondary high enough to produce a spark at the igniter. The reaction of the kick-coil helps to make the impulse current sufficiently large. The direction of flow of this impulse current is the same as that of the small amount of battery current that flows through the primary before the contact-points are separated.

If the battery current is now cut off, either by disconnecting one of the battery wires, or by moving the switch to its magneto position, both of which have the same effect, then rotating the magneto armature induces an alternating current in its primary winding. The direction of flow of this generated primary current at any instant is opposite that which the battery current had, as just described. The interruption of the generated current produces a spark at the igniter when the speed of rotation of the armature is sufficiently high.

While the switch is in its battery-magneto position, so that the battery is connected to the magneto as has been described, then the electromotive force generated in the armature primary by the rotation of the armature opposes the tendency of the

battery to send current through the armature primary. While the rotative speed of the armature is extremely slow, the battery current predominates in the armature winding. The ignition spark under this condition is due to the interruption of the portion of the battery current that flows through the contact-points.

At some speed of the armature slightly higher than that just mentioned, and at the instant the contact-points just begin to separate, the generated electromotive force in the armature primary just balances the tendency of the battery to send current through the armature primary. There is consequently no flow of current in the armature primary at the instant of interruption of the battery current, all of which flows through the contact-points just before its interruption. Under this condition the ignition spark is due to the interrupted battery current.

At high speeds of rotation, the electromotive force generated in the armature primary sends a current through the primary in the direction opposite that in which the battery current flows through it while the armature is not rotating, or is rotating at extremely slow speed. This generated current and the battery current flow together in the same direction through the contact-points of the interrupter just before the contact-points are separated. The separation of the contact-points then stops the flow of the generated current through the armature primary and sends an impulse of battery current through the primary in the direction opposite that in which the generated current was flowing. This sudden decrease of generated current and increase of battery impulse current is in effect a reversal of current in the primary, and it induces pressure in the secondary of the armature sufficient to make an ignition spark at the igniter.

At ordinary operating speeds of the magneto the electromotive force induced in the armature primary reduces the battery current to an amount less than that which flows while the armature is at rest or rotating at slow speed. Therefore, even though the switch is left in battery-magneto position while

FIG. 272.
Bosch Duplex Magneto for Fig. 269.

running, the battery does not deliver much current, and the operation of the system is chiefly on magneto current.

When the switch is set in its magneto position, the battery is cut out of circuit completely.

In the off position of the switch the battery is cut out and the wires between the magneto and the switch are connected together at the switch, thus short-circuiting the magneto primary so as to prevent the interruption of the primary current and the generation of pressure in the magneto high enough to cause an ignition spark.

Pressing the push-button while the switch is in its battery-magneto position breaks the battery circuit provided the armature of the magneto is in such a position that the contacts of the interrupter are separated. The sudden stoppage of current thus caused in the magneto primary induces a pressure in the secondary that forces a spark across the spark-gap of the igniter. But if the interrupter contacts are together so as to close the circuit through them, then, although pressing the button breaks the battery circuit and stops the flow of current, no ignition spark is produced. This is because the amount of battery current that flows through the magneto primary while the interrupter contacts are together is so small that it will not produce an ignition spark when it is interrupted.

If the battery is connected to the magneto in the reverse manner from that shown, so that the positive (+) side of the battery is connected to terminal 2 of the magneto, and the battery negative (−) to terminal 1, then, although the motor can be started by pressing the push-button or by slow rotation of the motor and the magneto, ignition will cease as soon as the motor gains some speed, the switch still remaining in battery-magneto position. This is because the battery current and the current generated in the magneto primary flow in the same direction through the primary. Under this condition the amount of current flowing through the interrupter contacts at the instant their separation begins is not sufficient to produce an ignition spark when the current through the contact-points is interrupted.

198. Magneto with Two High-tension Windings for Dual Ignition. — In this system, one of the two high-tension windings of the magneto is used in connection with its own set of spark-plugs, and the other high-tension winding with its own set of spark-plugs. Two ignition plugs are put in each combustion chamber and are caused to spark at the same instant on high-tension current from the magneto. One of these plugs is connected to one of the high-tension windings of the magneto, and the other plug to the other high-tension winding. The two plugs thus receive current from different windings. The interruption of the current in the primary winding of the magneto armature induces the sparks at the two plugs in the same combustion chamber at the same instant, as stated.

CHAPTER XXII.

HIGH-FREQUENCY ALTERNATING-CURRENT MAGNETOS.

199. Introductory. — The high-frequency magnetos described in this chapter can be substituted for the battery in battery ignition systems which have a trembler spark-coil and a timer for closing the low-tension circuit at, or slightly before, the instant of ignition, provided the trembler of the spark-coil is one that has a high rate of vibration. The trembler must be sensitive. In some such ignition systems a battery is used for starting, and the magneto is then switched on to supply the low-tension current. The battery is cut out when the magneto is switched on. The magneto does not of necessity rotate in synchronism with the motor, and can therefore be driven by a belt or other form of friction drive. The magneto is run at a speed high enough to generate a low-tension current whose alternations are rapid enough to cause only a slight variation in the instant of ignition so far as affected by lack of synchronism between the rotation of the magneto and motor. The rapidity of alternation of the current is limited by the degree of promptness with which the trembler responds to the magnetic attraction caused by the flow of current through the spark-coil. The inductive resistance of the spark-coil is also a factor to be considered in determining how rapidly the current can alternate.

Magnetos of this type have the advantage of being extremely simple in form and inexpensive.

200. The W. & S. magneto is shown in Fig. 273 in complete form. Figs. 274, 275, and 276 show groups of different parts of the magneto. Fig. 277 gives the positions of the inductor arms relative to each other; also the path of magnetic flux.

The armature winding *C* is a single spiral coil of insulated copper wire with terminals at *D* and D_1. This stationary coil encircles the neck between the two rotary inductor spiders *A*

and B, each of which has three arms. These spiders are pinned to a shaft K which runs on two ball bearings and is driven by a belt on the pulley E. One of the ball bearings is indicated by

FIG. 273. (*See also* Figs. 274, 275, 276, and 277.)

High-frequency Low-tension Magneto with Stationary Armature and Rotary Inductor. Wheeler & Schebler, Indianapolis, Indiana.

FIG. 274.

Parts Remaining after Magnets are Removed from Fig. 273.

the letter M. The bearing farthest from the pulley is supported by the end-piece P. The pole-pieces F and $F1$ are separated by

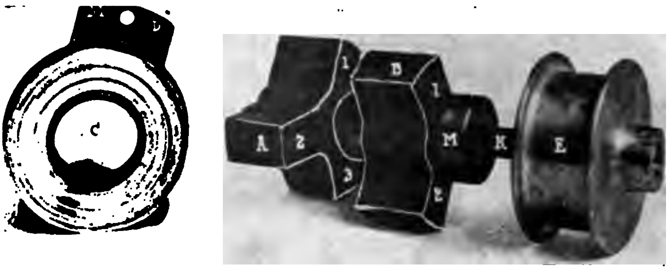


FIG. 275.

Inductor, Pulley and Spirally-wound Armature of Fig. 273.

the aluminum piece G (non-magnetic) and are fastened to the non-magnetic base H. The only moving part of the magneto is the rigidly connected group made up of the inductor spiders, the pulley, and the shaft upon which they are mounted.

In Fig. 277 the spider with the arms *A*1, *A*2, and *A*3 is in front of the armature coil *C*, and the spider with the arms *B*1, *B*2, and *B*3 is in the rear of the coil. It can be seen that the arms of one spider lie opposite the angles between the arms of the other. While the inductor is in the position shown in Fig. 277, the path of magnetic flux is from *N* along the broken line *L*, through the arm *A*1, then back through the neck of the inductor (and the opening of the coil) to the rear spider and out through the arm *B*1 to *S*. When the inductor has rotated one-twelfth of a revolution there is no magnetic flux through the neck between the two spiders. One of the spiders is then in the position shown in Fig. 276, neglecting the lettering of this figure. When the inductor has revolved clockwise one-sixth of a revolution from the position shown in Fig. 277, so as to bring the arm *B*2 opposite the pole-piece *F*1, and *A*1 opposite *F*, then the magnetic flux is from *N* into the inductor arm *B*2 and forward through the inductor neck to the spider *A*, then out through arm *A*1 to *S*. Similar changes of flux occur twice more during the remainder of the revolution. The result is that six impulses of current are generated during one revolution of the inductor.

Fig. 276.
End View of Fig. 274.

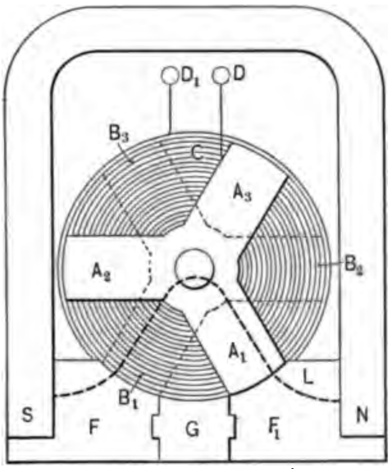
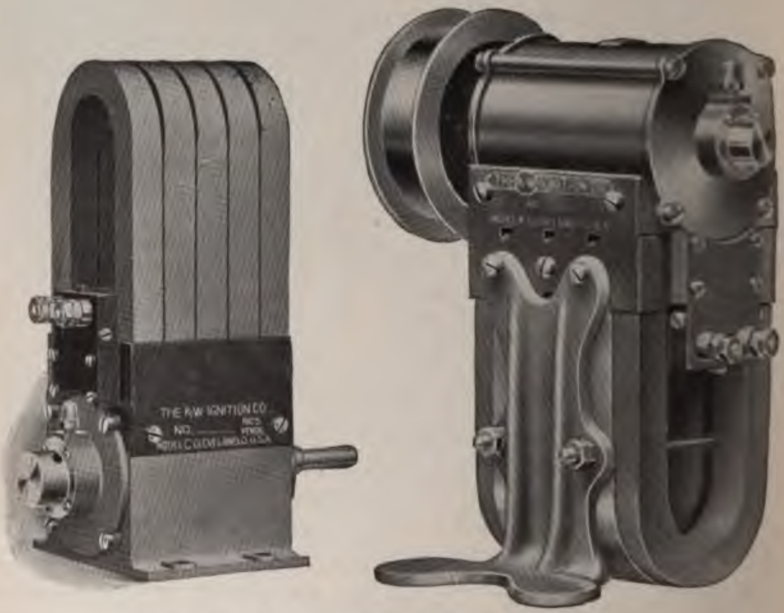


Fig. 277.
Outline of Fig. 273.

The rotative speed of the inductor should be about three times that of the motor crank-shaft for high-speed motors, and at a higher relative speed for slow-speed motors.

201. K-W High-frequency Magneto. — This magneto has a stationary spiral-wound armature coil and a rotary inductor with four arms. Fig. 278 is an exterior view of the type that



FIGS. 278 and 279. (*See also* Figs. 280 and 281.)
Two Forms of K-W High-frequency Magneto with Stationary Armature and Rotary Inductor. The K-W Ignition Company, Cleveland, Ohio.

has the armature and inductor at the bottom when the machine is set in the position that is in accordance with its design. Fig. 279 is designed to operate with the armature and inductor at the top. The internal construction is shown in Fig. 280. One of the straight bars, each of which forms two arms of the rotary inductor, is shown with its crowned end *A* nearest to the observer. The other bar of the inductor has its end *B* nearest to the observer. These bars are laminated. They are mounted on a shaft

FIG. 280.
View showing Armature and Inductor of Figs. 278 and 279.

and joined together by a large neck that is encircled by the armature coil *C*. The two arms, *A* and *B*, of the inductor are at right angles to each other, as shown in Fig. 281. This figure also shows the position of the armature and inductor relative to the pole-pieces *N* and *S* of the magnets.

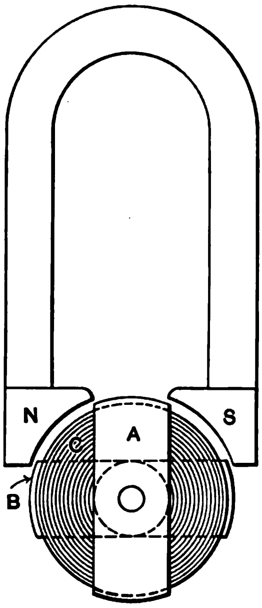


FIG. 281.
Outline of Field-magnets, Armature and Inductor of Figs. 278 and 279.

The action of this machine in generating a current is similar to that of the W. & S. magneto that has been described, except that the K-W machine produces four impulses per revolution of the inductor, instead of six.

The armature and the inductor are inclosed in a cylindrical case which is practically water-tight.

The makers recommend a speed from two and a half to three times that of the crank-shaft of a high-speed motor. For low-speed motors the magneto should have a higher speed as compared with that of the motor crank-shaft. It should not run much slower than for the high-speed motor.

202. The Ford high-frequency magneto has several spool-shaped armature coils spaced at equal distances in a circle, with the axes of the spools all parallel to each other and to the axis of rotation of the inductor. Fig. 282 shows sixteen spools mounted in this manner with their windings connected so that the coils are in series with each other. One pair of coils are not connected to each other, but the ends of the windings, one end for each coil, are left free for terminals. The inductor has several V-shaped magnets such as shown in Fig. 283. Sixteen of these magnets are bolted to the flywheel of the motor, with the angle of the V next to the center of the flywheel, as shown in Fig. 284. The north poles of the magnets are placed next to each other, and the south poles likewise next to each other. The magnets rest on a non-magnetic ring at about one-third of the length of the magnets in from their outer ends. The complete assembly is shown in Fig. 285, together with some of the transmission mechanism of an automobile. The spools are mounted on the stationary casing that incloses the fly-wheel and planetary change-speed gears.

FIG. 282.
(*See also* Figs. 283, 284, and 285.)
Armature of Ford High-frequency Magneto.

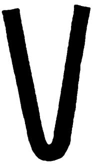


FIG. 283.
One of the V-shaped Magnets used in Fig. 284.

FIG. 284.
Rotary Magnet Inductor for Fig. 285.

Sixteen electric impulses are produced during each revolution of the flywheel (inductor) when that number of coils and of magnets are used. The current is passed through a trembler spark-coil in the usual manner, a timer being used to close the low-tension (magneto) circuit just before the instant that ignition is to occur in the motor.

While the rotor of the magneto is in such a position that the magnet-poles are opposite the ends of the coils, as shown in Fig. 285, then, taking any three consecutive coils, *A*, *B*, *C*, of which the middle coil *B* is opposite the north poles of two adjacent magnets, 1 and 2, the *S* pole of 1 opposite *A*, and the *S* pole of 2 opposite *C*, the magnetic flux is as follows: From the

FIG. 285. (*See also* Figs. 282, 283, and 284.)
Ford High-frequency Low-tension Magneto Embodied with Other Parts.

two *N* poles through the coil *B* to the casing which carries the coils. The flux then divides and goes in opposite directions through the casing to the cores of *A* and *C*. The portion which goes to *A* then goes through the core of that coil to the *S* pole of magnet 1 and on through the bar of magnet 1 back to its *N* pole. In a similar manner, the portion that goes to coil *C* goes through the core of *C* to the *S* pole of magnet 2 and thence through the bar of 2 back to the *N* pole.

When the inductor has rotated half the distance between the centers of two adjacent coils, so as to bring the magnet poles opposite the spaces between the coils, then there is no magnetic flux through the cores of the coils. When the inductor has

rotated from its first-mentioned position through a distance equal to that between the centers of two adjacent coils, so as to bring the magnet-poles opposite the coils again, the magnetic flux through the cores of the coils will be in the opposite direction from that for the first position mentioned.

CHAPTER XXIII.

VARYING THE TIME OF IGNITION. MULTIPLE IGNITION.

203. Advancing the Timer on Account of Lag in the Ignition Apparatus. — It has been stated, in connection with ignition systems which comprise a trembler interrupter, that, in variable-speed motors, the timer must be moved so as to interrupt the primary current earlier in the stroke of the piston when the speed of rotation of the motor crank-shaft is high than when it is low. The reason that was given for the necessity of thus advancing the timer was that there is a certain amount of lag in the operation of the ignition apparatus after the timer has closed the primary circuit, which lag covers the time interval between the instant of closing the primary circuit by the timer and the jumping of a spark between the ignition points of the igniter.

Since the time interval of lag, measured as a fraction of a second, is constant whatever the rotative speed of the motor, the rotative movement of the crank-shaft of the motor during the period of lag is greater when the motor is running fast than when it is running slowly. If the timer is set so that the spark jumps while the crank-shaft is in its dead-center position when the motor is rotated very slowly, as when turning it by exterior power for starting it, then the spark will not jump till after the crank-shaft has passed its dead-center position when the motor begins to run on its own power. The angular movement of the crank-shaft from its dead-center position to its position when the spark jumps will be greater when the rotative speed is high than when it is low. Thus, at 1000 revolutions per minute, the crank-shaft will move twice as far beyond its dead-center position before the spark jumps as it will when rotating at 500 revolutions per minute. The lag of the spark is proportional to the rotative speed of the motor when the timer remains at the same

position. In order to have the ignition spark jump at the instant the crank-shaft is passing through its dead-center position, the timer must be advanced as the speed of the motor increases. The amount of this advance is proportional to the speed of the motor, if the initial position of the timer is that which gives a spark at dead-center position of the crank-shaft when the latter is rotated at a very slow speed by exterior power, as has been stated.

In ignition systems whose interrupter is mechanically operated, the lag is much less than in one operating with a trembler interrupter. Mechanical interrupters of the types ordinarily used on magnetos entirely eliminate mechanical lag. This is also substantially true of other forms of mechanical interrupters in which the moving part which causes the interruption of the current is moved by a spring to cause the interruption, provided the spring-actuated part is of light weight and moved by a spring powerful enough to produce a very rapid movement.

In ignition systems operating with a trembler interrupter, the movement of the spark-control lever to advance the timer, ordinarily called "advancing the spark," does not actually advance the time at which the ignition spark jumps relative to the movement of the piston when the rotative speed of the motor is increasing, unless the advance of the timer is sufficient to more than counterbalance the effect of the increasing speed.

The advance of the timer in trembler-interrupter ignition systems must be greater than in those with mechanically operated interrupters. This is in accordance with the facts that have just been stated.

204. Variation of the Time of Ignition Relative to the Rate of Combustion of the Charge in the Motor. — This can be most conveniently discussed first in connection with motors which run at a constant speed.

The rate of burning (combustion, explosion) of the charge in the motor cylinder varies in accordance with the composition of the combustible mixture and the intensity of compression.

There is a certain proportion of air and fuel, for each kind of fuel, that burns more rapidly than a mixture containing either a greater or less proportion of fuel. The mixture which has

the highest rate of combustion may be called the normal mixture for that particular fuel. The proportions of air and fuel in the normal mixture are different for the different kinds of fuel, and the rate of burning is in general different for the normal mixture of each kind of fuel. In general, a normal mixture which has a high heating value has a higher rate of burning than a normal mixture which has a lower heating value. There are apparently exceptions to this statement, however, since some of the permanent gases used in combustion motors have a higher rate of combustion than others.

If a stationary engine operating on producer gas has its ignition properly timed for a normal mixture while the producer is delivering rich gas (of high heating capacity for that kind of gas), and the gas then becomes lean (of less heating capacity) after the manner of operation of producers, the combustible mixture going into the engine will then become lean if the setting of the proportioning device remains unchanged. The ignition will then have to be advanced to secure the most efficient results for the kind of mixture then received. This is because the lean mixture is slower burning than the normal mixture, and unless it is ignited earlier than the normal mixture, combustion will be completed too late in the stroke of the piston to secure the maximum impulse effect against the piston to drive it. In the same manner, if the ignition is properly timed for normal mixture when the producer is delivering lean gas, the ignition will have to be advanced if the gas coming from the producer becomes very much richer and the setting of the gas-proportioning device is not changed. In this case the over-rich mixture is slower burning than the leaner normal mixture. The variation of the timing is not so great in the latter case, however, as when the change is from a normal mixture using rich gas to lean gas. Upon setting the proportioning device so as to obtain a normal mixture with the rich gas, the ignition should be retarded.

Relative to variation in the intensity of compression of the combustible charge, ignition must be advanced when the compression is reduced, in order to secure the maximum amount of power from the charge ignited. Some engines, while operat-

ing on a normal mixture made from gas of a constant composition, are regulated to meet the varying demand for power by admitting to the cylinder an amount of mixture approximately proportional to the power which the engine is called upon to deliver. If an engine, governed to approximately constant speed in this manner, is operating on full load with its ignition properly timed, then if the load falls off so as to become light, the ignition must be advanced on account of the reduced compression and consequent lower rate of combustion. When the full load comes on again, the ignition must be retarded to its initial position. This refers to the time of ignition for obtaining the maximum efficiency in the use of the fuel.

The above statements, modified to suit the conditions, are applicable to motors using liquid fuel.

205. Varying the Time of Ignition with Variation of Speed. — Since the combustible mixture takes an appreciable amount of time to burn, or explode, in the motor cylinder, it must be ignited earlier in the movement of the piston when the motor is running at high speed than at low speed, in order to obtain the maximum amount of power from the fuel consumed.

The extent of the variation of the time of ignition in accordance with the variation of speed depends on the kind of ignition system used and the location of the igniter, or igniters, in the combustion chamber. An ignition system which gives a spark of constant strength regardless of the speed of rotation of the motor must have the time of ignition varied more with variation of speed than is the case for a system which gives a stronger, or hotter, spark as the speed of rotation of the motor increases. If the igniter is located away from the body of the mixture in the combustion chamber, as in the pocket over the valve, or between the valves, of some types of motors, then the ignition must be more advanced than when the ignition spark is made nearer to the center of the volume of the charge.

Most ignition systems operating on battery current give a spark whose strength is the same whatever the speed of the motor. On the other hand, most magneto ignition systems using current direct from the magneto give a stronger spark as the speed

of the motor, and consequently that of the magneto, increases. Less advance of the spark is, therefore, required in magneto systems of this nature than in battery systems. This statement applies to the actual occurrence of the ignition spark, or arc, and is not intended to include the lag which occurs in a system operating with a trembler interrupter. The lag due to the trembler makes additional advance of the timer necessary.

206. Reduction of Variation of Ignition by the Use of Two Simultaneous Ignition Sparks. — It is common practice in gas engines of large size to have two or more simultaneously operated igniters in each combustion chamber. These are generally located some distance apart and in such positions as to have at least one of them in the part of the combustion chamber where the mixture is such as to be easily ignited when there is a reduction in the amount of gas admitted on account of light demand for power. Aside from the greater certainty of producing ignition of the charge, the use of igniters at more than one place decreases the time required for combustion when ignition occurs at more than one locality. This is due to the fact that each of the propagating flames emanating from the points of ignition has a less distance to travel when ignition is at more than one point than when it is at only one point. The whole charge becomes inflamed quicker when ignited at two widely separated points than when ignited at one point only. Since combustion is completed more rapidly with ignition at two or more points, there is less movement of the piston and crank-shaft during combustion, and consequently less advance of ignition is required. This means that there is less variation of the time of ignition under different conditions of the composition of the combustible mixture and of compression of the charge.

The decrease in the time occupied by combustion, as this decrease is effected by the use of two simultaneous ignition sparks at widely separated positions, when compared with single ignition, is more decided when the single igniter is located at one side of the main volume of the charge. The results that have been obtained in a motor of the automobile type by trial in the laboratories of the Association of Automobile Engineers

are striking examples of this. The motor tested had its inlet and exhaust valves on opposite sides of the cylinders. During the trials with single ignition the spark-plug was located in one of the pockets in which the valves are located, and in the trials with double ignition, a spark-plug was located in each of the valve pockets. The use of the two plugs reduced the distance through which the propagating flame had to travel to slightly more than half of its necessary travel when one plug was used. The electricity was supplied by a high-tension magneto. The results showed not only a decided decrease in the advance of ignition required with increased speed when the two plugs were operated, but also a very decided increase of power, especially at high speeds. The two plugs also made it possible to run the motor at much higher speed while obtaining a large amount of torque.

207. Advancing and Retarding the Spark in a Variable-speed Motor. — On account of the extremely wide range of conditions under which an automobile motor operates, the proper manipulation of the spark control to obtain the most effective results affords a complete example of variation in the time of ignition.

When the motor is to be started by cranking, the spark control should be set so that ignition will not occur before dead-center position of the crank-shaft if the ignition is by battery current. When battery current is used, the motor can be started by extremely slow cranking. If the ignition were to occur before dead center while cranking very slowly, the first explosion in the cylinder would drive the crank-shaft of the motor backward, which is not only undesirable but dangerous to the operator. With magneto ignition the speed of cranking must generally be fast enough to carry the crank-shaft beyond dead-center position before the force of the explosion is great enough to stop the rotation, even if ignition does occur slightly before dead center. The latter statement is not intended to apply to magnetos which are provided with a spring device for snapping the rotor of the magneto over so as to produce an ignition spark when the motor is cranked at slow speed. Some such magnetos are so constructed as to make it impossible to obtain a spark before dead center when starting the motor by

external power. Those without such a retarding device must have the control set for late spark in the same manner as a battery system.

After the motor is started and while it is running light, as before the car is started, the throttle should be closed as far as possible without stopping the motor, and the spark advanced only far enough to keep the motor running at slow speed. This will use the least amount of fuel and cause the smallest amount of heating of the motor. When the car is to be started, the spark should be well retarded before opening the throttle to obtain the requisite amount of torque. While the car is running on a good level road, the throttle should be closed as far as possible and the spark advanced as far as possible without reducing the speed of the car. If the motor is at all worn so as to allow play in the working parts, too much advance of the spark will generally be indicated by a characteristic knocking or pounding in the motor, as well as decrease of power, as evidenced by loss of speed of travel of the car. Upon starting up a hill, in order to maintain the same speed of travel of the car, the spark must first be retarded slightly and the throttle then opened as much as is found necessary, or these two operations may be performed simultaneously if it is possible to operate both the spark and throttle controls simultaneously. The retard of the spark is necessary on account of the higher rate of combustion that accompanies the increased amount of the charge and the consequent increased intensity of compression pressure. The reverse manipulation of the spark and throttle are in order when the car has reached the top of the hill and again starts on a piece of good level road. If the speed of the car is to be increased gradually on a level road, then the throttle can be opened gradually without retarding the spark. The increasing speed of the motor compensates the increasing rate of combustion due to the larger charge and the consequent higher compression.

When the motor is pulling at slow speed of rotation on open throttle along a heavy road or up a hill, the spark should be well retarded, since otherwise there will be loss of power and, in a worn motor, knocking or pounding.

CHAPTER XXIV.

CARE AND ADJUSTMENT OF IGNITION SYSTEMS.

208. Introductory. — This chapter relates only to good ignition apparatus which is kept in order by proper care. It does not deal with the troubles that arise on account of neglect and inferior or defective apparatus. The latter are reserved for later discussion.

The ignition apparatus should be kept clean and properly lubricated. The insulated wires should be kept free from oil as far as possible. This is especially important relative to wires that carry high-tension current for jump-spark ignition. Oil destroys the insulating property of rubber insulation.

In case of unsatisfactory ignition suspected to be due to the ignition system, it is generally advisable to first make sure that the spark-plugs are clean and in order, and that the battery, if one is used while ignition is unsatisfactory, is capable of delivering the requisite amount of current. The examination and cleaning of a spark-plug, and the testing of a battery, can generally be readily accomplished.

It should always be remembered that there are other causes of unsatisfactory ignition than the ignition system itself. Prominent among these other causes is an improperly proportioned combustible mixture. This fault can ordinarily be remedied by adjusting the carbureter when one is used for liquid fuel, or the proportioning device when gas is used as the fuel. Water in liquid fuel is a cause of a lean combustible mixture, and leakage of water into the combustion chamber of the motor may cause ignition trouble on account of the water collecting on the igniter.

All of the matter given below does not relate to any one ignition system, but such parts as do relate to any particular system can be applied to it.

209. Cleaning the Spark-Plug. — It not infrequently happens that dirt collects on the insulation or between the spark-points of the igniter. This may be in the form of dry carbon or of carbon mixed with gummy residue of lubricating oil. The gummy deposit generally indicates that the oil used to lubricate the motor piston is unsuitable, but it may be due to an excess of lubricating oil that would not give the gummy residue if used in smaller quantity. Sometimes a flake of carbon from some part of the walls of the combustion chamber lodges between the ignition points and prevents the formation of an ignition spark or arc.

The plug can be cleaned, after removal from the motor, by the use of a stiff bristle brush and gasoline. A toothbrush or a small stiff brush such as is used for painting is suitable. A piece of cloth may facilitate the cleaning of some parts of the insulation. It is not generally advisable to take the plug apart unless it is of the separable type. It is sometimes difficult to get the parts of an ordinary plug together again so as to be gas-tight, and there is danger of breaking porcelain insulation. The insulation of a plug should not be scraped with any hard tool, such as a knife or screw-driver, that will roughen it, since the roughened surface would take on and retain dirt more readily than the smooth one.

The plug should not be screwed very tightly into the motor if it has a taper thread (gas-pipe thread), if it is replaced while the motor is hot, for when the plug and motor come to the same temperature the plug will bind more tightly in the motor.

210. Adjusting the Width of Spark-Gap in Jump-spark Igniters. — The width of the spark-gap in a battery ignition system should ordinarily be about $\frac{1}{32}$ of an inch, but a wider gap is sometimes used. Magneto makers generally recommend a spark-gap width, for magneto current, of 0.4 to 0.5 of a millimeter (approximately $\frac{1}{64}$ to $\frac{1}{50}$ of an inch) for plugs and magnetos of the size commonly used on automobiles. In magneto ignition systems for motors much larger than those used on automobiles, and in which the spark-plug and magneto are much larger than those for automobile use, the spark-gap

is wider. About $\frac{1}{32}$ of an inch is suitable for these large plugs.

The width of the spark-gap is often increased in a magneto ignition system by the burning away of the points. When the spark-gap becomes widened from this or other cause, it should be adjusted to the proper width. This can be done by bending the wire which forms one side of the spark-gap, or by adjusting the insulated spindle or other part of the plug, according to its design. It is convenient to have a gauge of the proper thickness to which the adjustment can be made. A piece of wire flattened at the end, or a piece of clockspring, is suitable. A silver dime is approximately $\frac{1}{32}$ of an inch thick after the raised edges are worn off.

If a bead of metal has formed at the spark-gap, or if the points or edges have become rough and irregular, it is advisable to file them to a more regular shape. The end of a wire may be filed off square across the length of the wire, thus leaving sharp edges from which a spark will jump more readily than from a smoothly rounded point.

211. Repairing the Spark-Points of Contact Igniters. — The spark-points of contact (low-tension) igniters generally become pitted and uneven where they make contact with each other. They should then be dressed with a very smooth-cut file so as to make good contact with each other. Care should also be taken to see that the points separate at least as much as $\frac{1}{32}$ of an inch when operated to draw the ignition arc. A much wider separation than this is customary in large plugs, and also sometimes in small ones. There is no objection, so far as the formation of the arc is concerned, to a wide separation of the contact-points. A large movement involves increased mechanical wear as compared with slight motion, however.

212. Adjusting the Trembler. — The trembler should be adjusted so that the least amount of battery current that will give a spark for satisfactory ignition is used. The amount of battery current that passes through the trembler can be measured by means of an ammeter inserted in the battery circuit. The amount of current required varies for different spark-coils.

For the more usual sizes of coils, from one-half ampere to one and a half amperes is required for operating a four-cylinder high-speed motor with four combustion chambers. In the absence of information as to the amount of current required for any particular system, it can be determined by trial.

If there is more than one trembler and spark-coil, then the current passing through each trembler should be measured separately and the tremblers adjusted so that all take the same amount of current. The current for one trembler is less than that for all of them, in proportion to the number of tremblers. The sound given out by the tremblers should be of the same pitch for each when all are of the same size and design.

It has been stated that some tremblers have only one means of adjusting them, while others have two.

In the absence of an ammeter for measuring the current, the tremblers can all be adjusted to the same pitch of sound as nearly as possible. In general, the rate of vibration of the tremblers should be somewhere near midway between the highest and lowest rate that will give ignition. Ordinarily more current flows when the rate of vibration is high than when it is low.

213. Lubricating and Cleaning the Timer. — When the timer is of the sliding-contact type, the rubbing surfaces should be kept well lubricated. This can be done by a copious supply of oil, or by packing the timer with soft grease if it is of a form that will retain grease in the casing. Some sliding-contact timers are continuously lubricated by oil pumped to them.

For a timer with roller contact, it is generally better to use oil for lubricating than grease. The grease is apt to prevent good electric contact between the roller and the stationary contact-pieces. If grease is used, it should be very thin.

A timer which makes only pressure contact (after the manner of magneto interrupter and trembler contacts), and is not intended to be submerged in oil, should not have any oil on the contact-points at which the circuit is closed. The oil sometimes prevents effective closing of the circuit when the contact-points are covered with it.

A timer should be cleaned whenever dirt has collected in it to an appreciable amount The dirt may be only small particles and is generally mixed with the oil or grease. A moderately soft bristle brush and kerosene are suitable for cleaning. Oil should be applied to the rubbing surfaces after cleaning.

214. Care of the Magneto or Dynamo. — A magneto or dynamo whose armature shaft runs on ball bearings requires only a very few drops of oil ~~on each bearing~~, including the bearings of the distributer shaft when there is such a shaft, about once a month in ordinary service. Those which have plain journal bearings and are equipped with oil reservoirs and wicks for keeping the bearings continuously lubricated require a little more oil about as frequently. Plain journal bearings without oil reservoirs and wicks or corresponding devices require frequent oiling, as two or three drops daily on each bearing when in continuous use.

In some magnetos the interrupter-lever is bushed with wood fiber where the lever rocks on the pin that supports it, and a piece of wood fiber is fastened to the end of the lever where it strikes the cam that operates the lever. The wood fiber works on the metal satisfactorily without lubrication under the conditions existing in interrupters of magnetos. When there are no other rubbing parts in the interrupter, no lubrication of the interrupter is necessary. There are other materials that can be used without lubrication, as the wood fiber is used in this case.

If the interrupter (contact-maker) has metallic surfaces that rub against each other, a slight amount of lubrication is generally necessary. Only a very small amount of oil should be used, however, so that there will not be an excess to collect between the contact-points and interfere with their operation by preventing good electrical contact between them.

Care should be taken not to use an excess of oil on any part of a magneto or dynamo. If too much oil is applied, some of it may get on the winding of the armature and injure the insulation. Oil is also undesirable on the commutator of a dynamo.

If much carbon dust or dirt collects in the neighborhood of a carbon brush, the brush should be examined to see whether it

has become much worn. If it is greatly worn, it should be replaced by a new one.

The magneto should be kept clean, especially the interrupter and the distributer. Carbon dust and particles of metal in the distributer are very apt to cause a short circuit and thus interfere with the ignition. The same is true to a less extent of the interrupter. A soft bristle brush or cloth may be used for cleaning either. If there is any oil present, kerosene or gasoline will facilitate the cleaning. Do not scrape the non-metallic parts with a steel tool. After using gasoline, all of the metal surfaces with which it came in contact should be coated with a little oil or kerosene, except the contact-points of the interrupter. The coating of oil can be put on with a piece of cloth or a small brush. It is not necessary to coat with oil after using kerosene for cleaning.

The contact-points of the interrupter of a magneto should be adjusted so that they separate from $\frac{1}{64}$ to $\frac{1}{50}$ of an inch to break the circuit. In very large magnetos the separation of the contact-points may be somewhat greater than this amount. The contact-pieces are generally threaded so that they can be adjusted. The lock-nut or other locking device should be tightened after adjustment, so as to hold the contact-pieces firmly in place.

The commutator of a small dynamo for ignition use seldom requires any attention, since the brushes are ordinarily of a material that is self-lubricating. The self-lubricating property is generally obtained by making the brushes partly of graphite. In the dynamo for supplying ignition current to several large engines, the brushes are not always of such material as lubricates well. In such a case, the commutator should be lubricated by applying a hard lubricant to the commutator while it is running. Sticks or "candles" of commutator lubricant can be found on the market.

If the commutator becomes very much roughened, it can be smoothed by holding a piece of fine-grained sandpaper (not emery paper or emery cloth) against it while it is running, first lifting the brushes from contact with the commutator. In case

of extreme roughness, the commutator can be filed smooth with a fine-cut file. The brushes should always be lifted from the commutator while doing this, and the armature run at as slow a speed as possible.

Water should not be allowed to get on the electric generator unless it is positively waterproof, as are some of those made for use on boats. Water injures the insulation, and in the interrupter it interferes with the breaking of the circuit if it gets between the contact-points.

215. Filing or Dressing the Contact-Points. — For filing the platinum contact-points of the interrupter of a magneto or trembler coil, only a very smooth (fine-cut, dead-smooth) file should be used. A convenient method of holding the threaded contact-pieces (contact-screws) of a magneto interrupter is to drill and tap a hole through a flat piece of metal somewhat thinner than the length of the contact-piece, and screw the latter into the threaded hole so that its contact-point projects slightly beyond the surface of the holder. The projecting end can then be filed level with the surface of the holder. If the hole is perpendicular (square) with the surface of the holder, the end of the contact-piece will then be square with its length, which is the proper method of making it. If the screw fits loosely in the holder so that it turns around while filing it, the holder should be slotted so as to split it through the length of the tapped hole. The screw can then be clamped tightly by gripping the holder in a vise so as to press the sides of the slot toward each other, or by putting a binding screw through the holder at right angles to the hole for the contact-piece.

The contact-points of large igniters of the make-and-break type can be filed down in a similar manner. A coarser-cut file can be used than for the small points. A very fine-cut file does not remove metal rapidly. It is advisable to finish with a smooth-cut file.

216. Care of Batteries in General. — A battery should be kept clean and dry. No metallic tools or appliances should be placed where they can come into contact with the terminals, since they may make a short circuit, thus causing rapid exhaus-

tion of the battery and unsatisfactory ignition. A storage battery is apt to be permanently injured by a short circuit made in this manner. A collection of dirt around and between the terminals, especially if moist, is enough of a conductor to allow the battery to discharge slowly through it.

If the pasteboard covering commonly used on individual dry cells becomes wet, it allows leakage of current through it when the cells of a battery are grouped against each other or when they are in a metal case without other insulation than that of the pasteboard. If the battery must be used after the pasteboard covering of the cells has become wet, they should be separated so as not to touch each other and should not be allowed to touch a metallic part so as to make metallic connection between their coverings. It is also unadvisable to have two or more of them in contact with the same piece, or connected pieces, of wet wood, but this is not so important as keeping them away from metal. In case of necessity of keeping them in use, the cells with wet covering can be separated from each other by pieces of insulating material, such as glass, porcelain, or rubber.

Corrosion of the terminals of a storage battery can be prevented by coating the terminals with vaseline, paraffine, or varnish after cleaning them thoroughly.

217. Keeping Electric Connections Tight. — The connections, or fastenings, between different parts of the ignition system should be kept tight so as to make good electric contact. This is more important in low-tension circuits than in high-tension ones, such as those of the secondary circuit in jump-spark systems.

The nuts of dry batteries of the ordinary form are especially given to working loose. Such a nut should be tightened hard against the wire which it holds, but not hard enough to break the wire or cut it in two. It is not bad practice to use pliers for tightening it. If the nut is loose on the thread it can generally be made tight by removing it and pinching the thread of the bolt part of the terminal between the jaws of a pair of pliers, or by striking the nut with a hammer so as to slightly close the hole. Or the nut may be secured in place with a drop of solder, after

tightening. These practices are decidedly not recommended for other parts of the ignition system, or for the terminals of storage batteries. If the cells of the battery are securely held in place so as not to shake about, there is very much less liability of the binding nuts working loose than when the cells can shake about.

218. Testing a Primary Battery.* — When an ammeter is permanently connected in the battery circuit, its reading while the motor is running is an indication of the condition of the battery, provided there are no unusual causes in other parts of the ignition system which effect a decrease in the amount of battery current. If there is some cause of decrease of battery current exterior to the battery, then a voltmeter connected to the battery terminals will indicate to some extent the condition of the battery. If the voltage of the battery shows normal while the system is operating on a reduced amount of current, then the trouble is outside of the battery, but if the voltage at the battery terminals is low as well as the current, then the battery is at fault. The fault may be loose connections between the cells of the battery.

If a primary battery is not delivering the requisite amount of current, it is advisable to test the cells separately with an ammeter. This can be done without disconnecting the cells from each other when they are of the type with exposed terminals. The test is made by applying the terminals of the ammeter to the terminals of each cell to be tested, after the manner that has already been described, and noting the amount of current as indicated by the ammeter. The terminals of both the cell and the ammeter must be clean so as to make good electric connection with each other. If the terminals are not clean or not pressed together firmly, the reading of the ammeter is apt to be misleading. If one of the cells is found to be very much exhausted, as indicated by the small amount of current that it sends through the ammeter, it is generally advisable to take it out of the battery, even though there may not be a good one at hand to replace it immediately.

* Testing storage batteries is discussed in the following chapter.

Connecting the ammeter to one of the cells individually in the manner just described may stop the motor. It is ordinarily sure to stop it if the ammeter is connected so as to test two or more cells at once.

A wet primary battery (one in which there is no absorbent material for retaining the liquid electrolyte) can be tested in the same manner as a dry primary battery. The internal resistance of a wet cell is greater than that of a dry one; therefore, the current that flows through an ammeter connected to the terminals of a wet primary cell, or wet primary battery, will be less than that from a dry primary cell or battery.

It is advisable to always use the same ammeter when testing a battery. The current that flows through an ammeter connected to a cell or battery terminals depends to some extent upon the resistance of the ammeter. The use of ammeters of different resistance at different times may therefore give misleading information.

On account of the varieties of forms and sizes of batteries and the different resistances of ammeters, it is not possible to state with any degree of accuracy how much current a battery or cell should give through an ammeter. It is advisable to compare the current obtained while testing a used battery with that of a like battery in good condition, the same ammeter being used in both cases.

The more thorough methods of testing storage batteries can be applied to primary batteries. These methods are given in the following chapter.

It has been stated earlier that an ammeter should not be applied to the terminals of a storage battery unless the ammeter is especially constructed for such use. Ordinary ammeters are not so constructed.

CHAPTER XXV.

TESTING OF STORAGE BATTERIES.

Caution. — Do not connect an ammeter alone to the terminals of a storage battery.

219. Voltage-and-current Test of a Storage Battery. — When an ammeter and a voltmeter are permanently connected into the ignition system so that the ammeter shows the amount of current that flows through the battery circuit while the ignition system is operating, and the voltmeter shows the corresponding pressure at the terminals of the battery, the current and voltage readings of the two instruments indicate fairly well the condition of the battery relative to the proportion of a full charge that is still in the battery, provided the battery is in good order. The voltage reading during the discharge should be compared with the voltage when the battery circuit is open, except the voltmeter circuit. The open-circuit voltage of two kinds of storage cells is given later in this chapter. These two kinds are the lead-plate cell and the nickel-iron cell.

A portable ammeter can of course be inserted in the battery circuit temporarily so as to obtain readings of the current delivered by the battery while the ignition system is operating, and a portable voltmeter can be applied at the same time to the battery terminals in order to measure the corresponding voltage.

An ammeter can be connected into an ignition system while it is operating without interfering with the ignition. This can be done in the following manner, first assuming that one side of the battery is grounded: Connect one terminal of the ammeter to the grounded side of the battery without removing the ground connection (ground wire) of the battery. Connect the other side of the ammeter to ground. The ammeter and ground wire of the battery are then in parallel with each other. Then

remove the ground wire of the battery. This leaves the ground connection through the ammeter as the only one directly between the battery and ground. All of the battery current must therefore flow through the ammeter, assuming that the battery has no circuits which are not grounded leading out from it. In a similar manner, an ammeter can be connected into any part of the battery circuit. This can be done in case the battery is not grounded. There must be no apparatus between the two points to which the ammeter is connected, and the portion of the regular circuit between the connecting points of the ammeter must be of low electrical resistance. An extreme method is to connect the ammeter to two near-together points of a wire and then cut the wire between the places to which the ammeter is connected. The wire must of course be bare and clean where the ammeter is connected to it. Before removing the ammeter the original connections must be made again.

A voltmeter can be connected to the terminals of a battery at any time without interfering with the operation of the ignition system.

220. Ammeter in Series with Resistance. — Probably the most satisfactory method of testing a storage battery while it is not delivering current to operate an ignition system (or any other apparatus) is by means of an ammeter in series with a resistance. The resistance should be of such a value as to allow the flow of a current approximately equal to that for charging the battery at the beginning of the charge. (The charging rate for some storage batteries is given later in this chapter.) One terminal of the ammeter should be connected to one terminal of the battery, and one terminal of the resistance should be connected to the other terminal of the battery. The current will then flow through the ammeter and resistance in series. The amount of current that flows is an indication of the condition of the battery when compared with the amount of current that flows under the same conditions when the battery is in good order and fully charged. A voltmeter used in conjunction with the ammeter and its series resistance will give additional information.

The resistance to be used in series with an ammeter in the manner just described can be determined approximately for any particular battery by dividing the voltage of the battery by the amount of current that is to flow. This is expressed by the formula

$$R = \frac{E}{C},$$

in which

C = amperes of current;
E = volts pressure of battery;
R = ohms of resistance.

If the average voltage of the battery is 6 volts while discharging at the rate to be used in the test, which will be taken as 5 amperes, then, substituting in the formula the values $E = 6$ and $C = 5$,

$$R = \frac{6}{5} = 1.2 \text{ ohms.}$$

It is on the safe side to first use a resistance larger than the 1.2 ohms thus obtained, and then decrease the resistance to obtain the desired amount of current. After the resistance is once determined in the latter manner it should not be changed, since such a change would be contrary to the method of making the test of the battery, especially when no voltmeter is used.

The resistance to be used in series with the ammeter may be in the form of a bare wire exposed so as to radiate the heat generated by the current passing through it, of a rheostat, or of wire embedded in enamel. A sufficient number of low-resistance incandescent lamps, in parallel with each other and the group of lamps in series with the ammeter, are suitable. The amount of current that will flow through the lamps in parallel with each other is approximately proportional to the number of lamps of equal resistance, under the conditions mentioned. The wire embedded in enamel can be made up in a form convenient for portable use. Special resistance, or rheostat, wire is generally used for such purposes as the above, but ordinary iron or steel wire will answer for a time at least. The resistance of an

iron wire 25 feet long and No. 18 American wire gauge is about 1.2 ohms. As the wire becomes hot its resistance increases.

221. Lamp for Testing. — An incandescent electric lamp which glows at a voltage the same as that of the storage battery to be tested is a convenient means of testing such a battery. If the lamp requires only a small proportion of the amount of current that the battery can deliver at its maximum safe rate of output, then the lamp can be connected to the terminals of the battery while the latter is delivering current for ignition. If the lamp glows only dimly, it is an indication that the voltage of the battery is lower than it should be. It should be remembered that a lamp which glows brilliantly in the dark will appear dull in daylight, and very dull in bright sunlight.

222. Testing Cells Individually. — Each cell of the storage battery should be tested separately when the battery is of the open type such that the terminals of the cells can be readily reached. Each cell of a battery should give the same readings when tested with the same testing instruments. In the case of portable storage batteries which are sealed so as to prevent spilling of the liquid, the terminals of the individual cells are generally so inclosed in the battery box that they cannot be reached for testing without unsealing the cell. This is not generally advisable unless the battery is in a bad condition which cannot be remedied without unsealing it. The trouble may be due to the electrolyte not being of the proper strength, which can be remedied without unsealing the cell.

223. A voltmeter test of a storage battery that is on open circuit is of practically no value alone when the battery is in good order, since the voltage of the battery on open circuit is practically the same whether the battery contains a large or a small proportion of its full charge. If the battery is in extremely bad order, the voltage may be low.

224. Voltage-drop Test. — Tests which show when a rapid drop of voltage begins while the battery is discharging at a constant rate are valuable for indicating the proportion of the charge that still remains in the battery. Since there may also be a rapid drop of pressure just at the beginning of a discharge

after the battery has been fully charged, the actual voltage must also be taken into consideration in the absence of knowledge as to about how much electricity the battery has given out since it was charged.

225. Lowest Safe Voltages of Storage Batteries While Discharging. — It has been stated that when a storage battery is discharging, the drop of voltage between the terminals of the battery is less while the battery is delivering a small current than while it is delivering a large one. The current which a storage battery is called upon to furnish an ignition system is generally small in comparison with that which the battery is capable of furnishing continuously for a shorter period of time covering its complete discharge. The current supplied to the ignition system is also generally small in comparison with the amount of current sent through the battery while charging it at the normal rate. Since storage batteries especially intended for ignition service are not generally rated with regard to the maximum amount of current (amperes) they can deliver efficiently throughout the entire period of discharge, and since the normal rate of current flow while charging them is generally given and should always be known, it is convenient to refer the rate of discharge to the normal rate of charging.

While a lead-plate storage battery is discharging at a rate which is about one-fifth to one-fourth of the normal rate of charging the battery, the discharge should not be continued after the voltage (while discharging) has dropped to 1.8 volts for each cell of the battery, and the discharge should not generally be continued long after the voltage (measured while discharging) has dropped to 1.9 volts. The safe minimum voltage is not the same, however, when the battery is new as after it has been charged and discharged several times, and it is somewhat lower when the electrolyte is weak than while it is up to full strength for the discharged condition of the battery. The normal average voltage of a lead-plate storage battery, while discharging at the rate common to ignition service, is 2.0 volts, or slightly more, per cell.

In the nickel-iron storage battery the voltage should probably

not be allowed to drop below 1.1 volts per cell while the battery is discharging at a rate as low as one-fourth of the charging rate of the battery. The minimum allowable voltage may be slightly lower, however, if the electrolyte is below its normal strength. The normal average discharge voltage of a nickel-iron storage battery, while delivering current at the low rate mentioned above, is slightly more than 1.2 volts per cell.

The greatly increased rapidity of the drop of voltage, which begins shortly before the battery is discharged as far as it should be, is the surest indication of the nearly complete discharge of the battery. After the rate of drop becomes rapid the battery discharge should be stopped. Discharge carried on after this condition has arrived is very apt to be injurious to the battery.

226. Curve of Voltage Drop While a Storage Battery is Discharging. — In Fig. 286 the curved line represents the voltage of

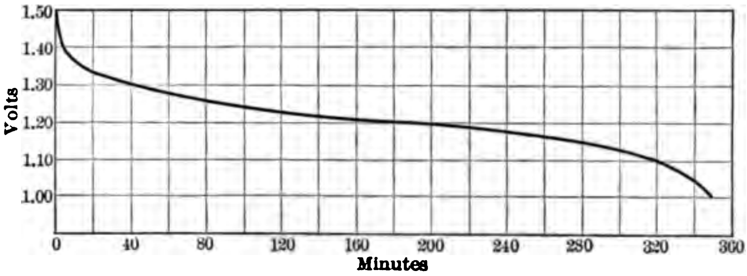


FIG. 286.

Curve Showing Voltage Drop of Nickel-iron Storage Battery while Discharging to Advisable Limit.

a nickel-iron storage battery discharging at its normal rate (with other conditions also normal). The voltage drops rapidly during the first five minutes or so, then the drop becomes more gradual, and has a minimum rate at about the middle of the discharge, then becomes more rapid again at the end. The battery is practically discharged when the voltage has dropped to 1.0 volt. If the rate of discharge were slower, the voltage at the same stage of discharge would be higher.

227. Testing the Density of the Electrolyte. — Apparatus suitable for testing the density of the electrolyte for a storage cell is shown in Fig. 287. It consists of a tubular testing glass for holding the portion of the electrolyte to be tested, a syringe for withdrawing some of the electrolyte from the cell and putting it into the testing glass, and a hydrometer which is to be immersed in the electrolyte for determining its density. The stem of the hydrometer is graduated so that a reading can be taken at the surface of the liquid. The hydrometer does not sink so deep

Fig. 287.
Hydrometer, Testing Glass, and Syringe.

into a liquid of high density, or high specific gravity (a heavy liquid), as into one of lower density. A strong electrolyte has greater density than a weak one.

The stem of the hydrometer may be graduated to read in density (specific gravity), but of those found on the market some are graduated to a different scale. Of these other scales the Baumé is found most often. The following table gives the densities corresponding to a portion of the graduations of a Baumé hydrometer sufficient for testing the electrolytes most commonly used in storage batteries.

DENSITY COMPARED WITH BAUMÉ HYDROMETER.

Baumé Degrees.	Density.	Baumé Degrees.	Density.	Baumé Degrees.	Density.
20	1.152	25	1.197	30	1.246
21	1.160	26	1.206	31	1.256
22	1.169	27	1.216	32	1.267
23	1.178	28	1.226	33	1.277
24	1.188	29	1.236	34	1.288

A more compact device for testing specific gravity is shown in Fig. 288. The hydrometer is inclosed in the glass body of the

FIG. 288.
Combined Hydrometer and Syringe.

syringe, so that, by drawing a sufficient amount of the liquid into the syringe to make the hydrometer float, a reading can be obtained.

A thermometer is a necessary accessory to the hydrometer testing set if the electrolyte is sometimes warm and sometimes cool when it is tested. The electrolyte has less density when warm than when cool, within the range of temperature that is allowable during the operation of the battery. Within this range the density decreases about .001 for 3 Fahrenheit degrees rise of temperature. Accordingly, if the density is 1.280 at 80° Fahrenheit, a rise of temperature of 30 degrees (to 110° Fahrenheit) will cause a density drop of $\frac{30}{3} \times .001 = .01$, thus making the density 1.270 at the higher temperature.

Ordinarily the temperature of the electrolyte is supposed to be at about 80° Fahrenheit when speaking of its density.

The electrolyte should be returned to the same cell from

which it was withdrawn, in order not to lower the level of the liquid in the cell.

The density of the sulphuric-acid electrolyte for one prominent make of storage cells of the lead-plate type is recommended by the manufacturer to be between 1.275 and 1.300 while the cell is fully charged. The lower density just given drops to about 1.20 by the time the cell is fully discharged, and retains this lower value during the time the cell remains discharged. It is not injurious to use a slightly lower density down to 1.25 in the fully charged cell for a while. The density in the discharged cell is correspondingly lower with this weaker electrolyte.

The potassium-hydrate electrolyte for the nickel-iron Edison storage battery is 1.200, as recommended by the manufacturers of the battery. The specific gravity does not vary appreciably during the charging and discharging of the battery under normal conditions. It is stated by the manufacturer that the efficiency and capacity of the battery is not affected materially by allowing the density of the electrolyte to become as low as 1.16, but that if it gets below this the output of the battery will be temporarily affected.

CHAPTER XXVI.

CHARGING AND CARE OF STORAGE BATTERIES.

228. Precautions. — When charging a storage battery the following three important items, among others, should be remembered:

First Item. — Only a direct current can be used. An alternating current will not charge the battery and is apt to injure it. But an alternating current can be transformed into a direct current that is suitable to charge the battery.

Second Item. — The positive (+) terminal of the charging source must be connected to the positive (+) terminal of the battery, and the negative (−) terminal of the charging source to the negative (−) terminal of the battery, but suitable resistance must generally be placed in the circuit to regulate the current to the proper amount. Methods of determining which is the positive side of a circuit and which the negative, have been given earlier.

Third Item. — An excessive current must not be allowed to pass through the battery. It is injurious and will overheat the battery if continued long.

229. Connections for charging a storage battery from a lighting circuit of fixed voltage are shown in Fig. 289. If the charging is to be done at the rate of 6 amperes, then 12 lamps of 16 candle-power each, or 6 lamps of 32 candle-power each, of the ordinary carbon-filament type, can be used as the resistance. The lamps are used in parallel with each other. If some other kind of incandescent lamp of higher efficiency (requiring less current per candle-power) is used for the resistance, then more lamps will be required. Thus, if each lamp takes one-third of an ampere, 18 lamps will be required.

If one side of the circuit from which current is to be taken is grounded, as in the case of most electric railway circuits, then the corresponding side of the battery should be connected to

ground without any resistance of substantial value between the battery and ground. If the main resistance is placed between

Fig. 289.
Lamp Resistance and Switch Connected to a Storage Battery for Charging the Battery.

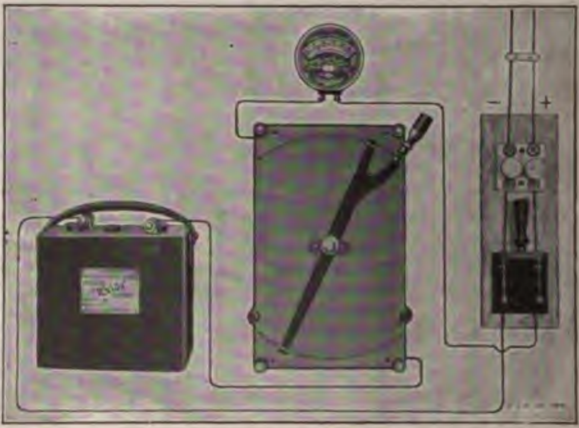


Fig. 290.
Rheostat and Switch Connected to a Storage Battery for Charging it.

the battery and ground, there is probability of the operator receiving a dangerous shock.

A fuse-block with two fuses is shown just above the switch

at the right-hand side of the illustration. The fuses are of the type commonly used in lighting circuits.

In Fig. 290, a rheostat is used for the resistance in the charging circuit; also an ammeter for measuring the charging current. The rheostat is used to vary the amount of resistance in the circuit, so as to regulate the current to the desired amount at any time.

The resistance required in the charging circuit can be determined by the formula

$$R = \frac{E - e}{C},$$

in which

C = amperes of charging current;
E = voltage of the charging circuit;
e = voltage of the storage battery;
R = ohms of resistance.

If the voltage of the charging circuit (line voltage) is 110 volts, and that of the battery is 6 volts, then, if the charging is to be done at the rate of 4 amperes,

$$R = \frac{110 - 6}{4} = \frac{104}{4} = 26 \text{ ohms.}$$

It is advisable to make the resistance somewhat larger than the value determined in this manner, to allow for variation in the line voltage and to be able to get a smaller current if desired.

230. Connections for charging two batteries at the same time are shown in Fig. 291. As illustrated, the two batteries are supposed to be in one box. Each battery consists of three cells connected in series. The two batteries are not electrically connected together.

The positive terminal of the main battery is at A; its negative terminal is at B. The positive terminal of the reserve battery is at P, and its negative terminal is at N. C is the charging circuit; D is a double-pole double-throw switch; E is a single-pole single-throw switch for the reserve battery. At M are six lamps for resistance in the main battery circuit, and at R is one lamp for resistance in the reserve battery circuit.

The purpose of having a large and a small battery in the same box, as just shown, is that the large one can be used till it is

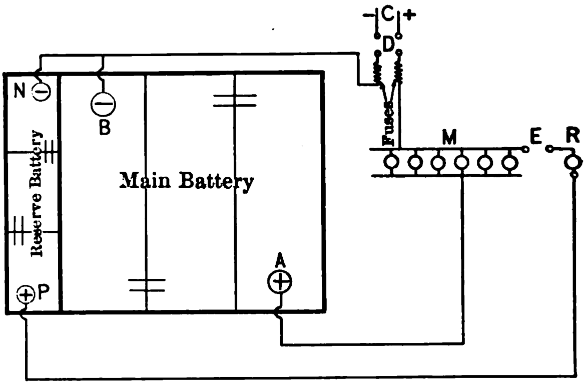


FIG. 291.
Connections for Charging Two Storage Batteries at the Same Time.

fully discharged, and then the small one can be used to supply current for a short time till recharging can be done.

231. The rate of charging a storage battery should always be given in instructions accompanying it. In the absence of such information the matter given in the following two sections will serve as a guide. On account of the differences in the form and construction of batteries, it is not possible to make accurate statements to cover the different varieties.

232. Charging and Care of Lead-plate Storage Batteries. — The following is extracted from the instruction book for "Exide" batteries of the portable type sealed in a case and intended for ignition use:

"When a battery is received, remove and discard the soft rubber caps from the vent-plugs and see if the electrolyte (the liquid in the jars) is at the proper height (about one-fourth inch, but not more) above the top of the plates; if it is lower, add electrolyte of 1.300 specific gravity.

"The battery should not be discharged below the point of exhaustion, i.e., 1.80 volts per cell when the current is flowing; thus, with a 3-cell battery, the voltage should not be allowed to fall below 5.40 volts. Nor should it be allowed to stand com-

pletely discharged. Never attempt to test the condition of the cells with an ammeter, as is the practice with dry cells.*

" Immediate recharging is necessary when the discharge limit is reached. If it is not possible to fully charge at once, then a partial charge must be given, and the charge completed as soon as possible and before again discharging.

" Always charge the battery at least once every two months, whether used or not; this rule also applies if the battery is to be out of service for any length of time, say for the winter months.

" When the battery is to be charged, unscrew the vent-plugs, observe the height of the electrolyte, and add pure fresh water if low, bringing the height up to one-fourth inch above the plates, but not higher.

" Charge at the rate given on the name-plate on the case, until there is no further rise in the voltage of the battery and each cell has been gassing or bubbling freely for at least five hours, and there is also no further rise in the specific gravity of the electrolyte over the same period. The voltage at the end of the charge may be between 2.40 and 2.70 volts per cell, depending on the temperature and age; the higher voltages are obtained on new batteries with the temperature low; on old batteries at high temperatures the low voltages are obtained. It, therefore, must be understood that, in determining the completion of the charge a fixed or definite voltage is not to be considered, but rather a maximum voltage, as indicated by there being no further rise in the voltage over a period of five hours. It is of the utmost importance that the charge be complete.

" The temperature of the electrolyte during charge should not be allowed to get above 100° Fahrenheit, unless this cannot be prevented, due to high temperature of the atmosphere. If it tends to do so, either reduce the charging rate or discontinue charging until the temperature has fallen. Low temperatures are in no way injurious, but they have the effect of temporarily reducing its discharge capacity; a return to normal temperature restores the capacity.

* AUTHOR'S NOTE. An ammeter can be used in series with a suitable resistance, however, as described in the chapter on " Testing of Storage Batteries."

"After charging, replace vent-plugs and wipe off top and sides of case.

"Great care should be taken not to bring a naked flame near the openings in the top of the battery during or immediately following a charge.

"The proper specific gravity of the electrolyte at the end of the charge is 1.300 * * *, but a variation of from 1.275 to 1.300 is allowable. Do not adjust the specific gravity except when a battery is fully charged; after adjusting, charge for an hour, in order to thoroughly mix the liquid just added with the electrolyte. Do not add electrolyte until it is determined that the specific gravity cannot be brought up to the proper point by charging. To add water or electrolyte, use a rubber syringe (see Figs. 287 and 288). Addition of electrolyte is but seldom necessary.

"The electrolyte can be made by mixing especially pure sulphuric acid (1.840 specific gravity) and distilled water in proportion of two parts of acid to five parts of water, by volume. The acid must always be poured into the water, and not the water into the acid. A glass, earthenware, or other acid-proof vessel, thoroughly cleaned, should be used, and the electrolyte allowed to cool before using.

"The height of the electrolyte in each cell should be observed, not only at the time of charging, but frequently between charges, and if it is low, either because of evaporation or spilling, it should be brought to the proper height (one-fourth inch above the top of the plates) by the addition of pure water. If a considerable amount of the electrolyte has been spilled out of the cells, then the battery should be given a special charge as soon as the water has been added, and the specific gravity adjusted to the proper point by adding some new electrolyte as soon as the charge is completed.

"The sediment, which gradually accumulates in the bottom of the jars, should be removed before it reaches the bottom of the plates, as, if it does, it is very harmful to them. The need for cleaning is indicated by lack of capacity, excessive evaporation of the electrolyte, and excessive heating when charging.

When a battery requires removal of the sediment, better results follow if the work is done at a place where they are accustomed to it.

" Keep the holes in the vent-plugs clear.

" Keep all connections tight and clean."

The charging rate for "Exide" batteries, of which other items are tabulated on page 109, is as follows:

Ampere-hour capacity at service rate,	40	60	80	100
Charging rate in amperes	4	6	8	·10

It may be seen that the charging rate can be obtained by dividing the ampere-hour capacity by 10.

In order to maintain a constant charging rate, the resistance in the charging circuit must be reduced as charging progresses, if the voltage of the source of electric supply remains constant. It is not objectionable, and often advisable, to charge at a slower rate toward the completion of the charge than during the early portion.

233. Removing Sediment from Lead-plate Cells. — In order to remove the sediment which collects at the bottom of a cell, the plates and electrolyte must be taken out of the containing vessel, which is usually called the " jar." It may be necessary to cut some of the lead connectors between the plates or between cells.

The cell should first be fully charged so that the voltage remains constant for an hour or so during the latter part of charging.

As soon as the plates are removed from the jar, they should be stood on edge, with one of the side edges at the bottom and the other side edge at the top, and the separators withdrawn from between the plates. The removal of the separators is facilitated by spreading the plates apart slightly. Then without delay wash the plates with a gentle stream of water, as from a hose without a nozzle. Such of the separators as are in a condition to be used again after cleaning, should be washed clean. If the electrolyte is to be used again, it can be put into another jar, as by siphoning it out or pouring carefully so as not to stir

up the sediment. As soon as the jar is cleaned, the plates can be put back in place, and the cut lead connectors "burned" (fused) together again. The burning process involves skill and practice, and will not be described here. The electrolyte should be put in the jar so as to cover the plates again as soon as they are in place, for the plates should not be allowed to become dry. If new wooden separators are put in the cell, the electrolyte should be made about 3 per cent higher in specific gravity than it was at the time of taking the cell apart. This is to allow for the diluting effect of the water contained in wet wooden plates.

234. Taking a Lead-plate Cell out of Commission. — If the cell is not to be used for several months, and it is not convenient to charge it at intervals while not in use, then, after being fully charged so that the voltage remains constant for an hour or so, it should be taken apart, washed, and the plates dried. The taking apart and washing can be done as just described. As soon as the positive plates become dry, they are ready for storage.

But if the negative plates become so hot as to steam while drying, they should be washed again, or wet with water, and allowed to dry again. They are then ready for storage.

If the cell has wooden separators between the plates, and they are thought worth keeping, they should be immediately put in water or electrolyte of low specific gravity, and left there during storage.

235. Charging and Care of Nickel-iron Storage Batteries.— The normal charging rate for an Edison nickel-iron battery can be obtained by dividing the rated ampere-hour capacity by 5. The normal length of time for charging is 7 hours, but continuing the charge 3 hours longer will increase the output capacity of the battery about 30 per cent. The charging current can be continued at its normal rate till the end of the charge if the temperature of the cell does not rise above 100° Fahrenheit. If the temperature tends to rise above this point, the charging rate should be decreased or the cell kept cool by some artificial means, as blowing a current of air against it with a fan.

The voltage rises rapidly at the beginning of the charge, sometimes to a value within an hour or two that apparently indicates that the battery is charged; but the voltage then drops somewhat below this amount and gradually rises again to a maximum value, which remains constant at the end of the charge. This maximum value generally lies between 1.80 and 1.85 volts per cell. Charging should be continued for 30 or 40

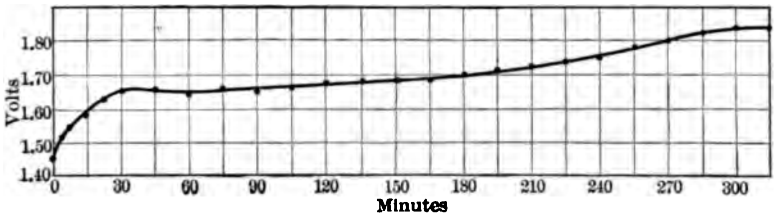


FIG. 292.

Curve Showing Rise of Voltage while Charging a Nickel-iron Storage Battery.

minutes after the voltage becomes constant and is as high as 1.80 volts.

Fig. 292 shows the curve of voltage variation of a nickel-iron cell while it is being charged.

Higher rates of charging can be used for a short time, — as high as double the normal rate for an hour, — but the temperature should not be allowed to exceed 100° Fahrenheit.

A lower rate of charging can be used, as when the charging source will not supply the normal amount of current, but this lower rate should not be less than two-thirds of the normal rate. Very low rates of charging are injurious.

When a new nickel-iron battery is first assembled and put into use, it should be charged at the normal rate for about 15 hours. The same applies to putting a battery into use again after it has been out of commission.

There should always be enough electrolyte to keep the tops of the plates covered. Overcharging causes loss of water from the electrolyte by decomposing the water. This loss of water should be replaced by pure distilled water which is newly dis-

tilled, or has been kept in a tightly closed vessel to prevent carbonation by contact with the atmosphere.

The specific gravity of the electrolyte does not change during charging and discharging, except possibly on account of loss of water as just stated. Its normal specific gravity is 1.200. Density tests should be made at the end of a charge; the liquid is then thoroughly mixed.

Before putting in new electrolyte it is better to throw away all of the old.

Cleaning the cell is limited to the outside. The containing vessel (can) is so constructed that it cannot be opened to remove the plates without injuring it.

236. Taking a Nickel-iron Battery out of Commission. — It is not necessary to charge the battery when it is left idle.

" A battery can be put out of commission indefinitely if care is taken to see that the outside of the retaining cans is left clean and dry, and that the cells are in a discharged condition. It should be stored in a dry place, and will require no attention other than an inspection once in two or three months to make sure the solution is kept at its proper height."

CHAPTER XXVII.

TIMING THE IGNITION.

237. General Features. — In the more general cases the requirements of the ignition system relative to the time of ignition are that it shall cause ignition as early as desired during the compression stroke of the motor while the motor is running, and that, while the motor is being started, it shall not cause ignition until after the piston of the motor has started on its impulse, or combustion, stroke.

The following statements regarding the setting of the timer, the contact maker, or the magneto rotor, are intended to point out general methods of meeting these requirements. In view of the numerous kinds of ignition systems and the varied nature of the mechanical part of their operation, the method which best meets the requirements of each specific case should be selected and, if necessary, suitably modified.

The instructions of the manufacturer of the apparatus should be followed in preference to the general instructions given herein.

When the connections to the ignition control are apt to have considerable lost motion on account of wear or loose fitting, an allowance should be made for this lost motion.

In a system which will give an ignition spark or arc, however slow the rotation of the crank-shaft of the motor, such as a system operating on current from some source which will supply current whether the motor is rotating or not, a timer operating in conjunction with a trembler spark-coil or with a magnetically operated igniter must not close the circuit, when the spark control is in position for latest ignition, until after the crank-shaft of the motor has passed its dead-center position; and an interrupter must not break the circuit until after the crank-shaft has passed its dead-center position when operating on current similarly supplied.

Precaution should be taken to prevent an impulse of the motor while timing the ignition. The removal of the spark-plug or disconnecting the wires from it, in a high-tension system, will prevent ignition. In a low-tension system, the opening of a petcock so as to connect the combustion chamber with the atmosphere will prevent an impulse of the motor. In the absence of the petcock, some part may be removed to make an opening into the combustion chamber. If there is no combustible mixture in the motor, there can of course be no ignition without these precautions. But certainty in this respect is apt to be like that regarding a gun which is not loaded.

238. Timing, or Setting, a Timer. — This can be done by either of the following two methods, according to which is the more convenient:

First Method. — Rotate the crank-shaft of the motor somewhat past one of its dead-center positions, say 10 to 20 degrees of angle past, so that one of the pistons has moved a slight distance on its impulse, or combustion, stroke. Leave the crank-shaft in this position.

In a jump-spark system, disconnect the wire from the spark-plug for the cylinder whose piston is on the impulse stroke, and place the disconnected end of the wire within an eighth-inch from the metal of the motor; or remove the spark-plug from its position and place it so that its outer bushing makes contact with the metal of the motor, but its insulated spindle and the end of the connection to it do not make electric connection with the metal of the motor.

Loosen the timer rotor from the part (shaft) that drives it, so that the timer rotor can be revolved without rotating its driver with it. Move the spark control to its position for latest spark. Moving the part of the timer to which the control is connected around in the direction of rotation of the timer rotor retards ignition.

Revolve the timer rotor slowly in the direction that it rotates while operating, until it closes its circuit, as indicated by a spark at the plug mentioned, or by movement of the magnetic igniter corresponding to the cylinder whose piston is on the com-

bustion stroke, as the case may be. Fasten the timer rotor to its driver permanently in the position thus determined.

Judgment must be used in selecting the value of the angle of the crank-shaft past dead center for timing in this manner. If there is probability of much wear in the control connections, the angle should generally be made more than 10 degrees when the motor is to be started from rest or from extremely slow speed of rotation, by the impulse of an ignited charge in its cylinder.

The movement of the spark control must be sufficient to give the greatest advance desired.

If the timer rotor is mounted on a shaft separate from the cam-shaft or crank-shaft, and which is only for driving the timer rotor, then the desired setting of the rotor can be obtained approximately by taking the driving gears out of mesh with each other and then putting them into mesh again in the desired position. The accuracy of adjustment by this method is limited to half of the angular movement of the timer rotor due to moving the gear on its shaft one tooth forward or backward relative to the gear which meshes with it. This method can be used, under the restrictions mentioned, when the timer rotor and its gear are keyed or otherwise fastened permanently in position on the shaft. It is immaterial whether the timer shaft also drives a pump for cooling water or lubricating oil.

Second Method. — Bring the crank-shaft to one of its dead-center positions so that one of the pistons is at the end of its compression stroke and ready to begin its impulse stroke.

Loosen the timer rotor from the shaft or other part that drives it, so that the timer rotor can be revolved without rotating its driver with it.

Move the spark control to the position thought to be correct for ignition at dead center while the motor crank-shaft is rotated at very slow speed, as when starting the motor. This position, for a high-speed motor, would generally be not more in advance of the position for latest ignition than one-fifth of the entire movement of the control. It may be more in advance for a slow-speed motor.

The remainder of the timing is the same as that in the second, third, and fourth paragraphs of the first method, just given.

239. Timing a Rotary Magneto of the Interrupter Type. — It should always first be made certain that the magneto itself is so adjusted that its interrupter breaks the primary circuit in accord with the proper corresponding position of the rotating armature or inductor. The ordinary method of determining this in a magneto with rotating armature is by measuring the distance *A* in Fig. 293 between the lip of the pole-piece and the edge of the armature core, after the core has passed beyond the position in which its crowned parts bridge the space between the pole-

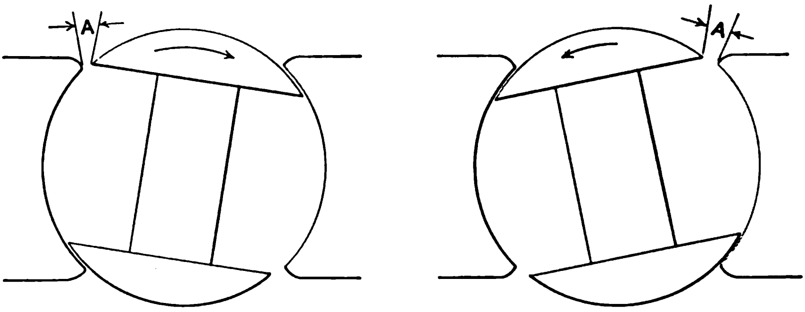


Fig. 293.
Position of Armature for Timing a Magneto by the Advanced Spark-control Method.

pieces. The arrows indicate the direction of rotation of the armature. The distance *A* is as small as one-sixteenth inch for some magnetos, and as large as one-fourth inch or larger, in others. This depends on the size of the magneto and form of the pole-piece lips, among other things. Sometimes there is a reference mark to indicate the position of the armature at the instant that the interrupter contacts should begin to separate. In the absence of such a mark, the instructions of the manufacturer should be consulted.

Either of the following two methods of timing the magneto may be followed:

First Method. — Set the crank-shaft of the motor in the position through which it is to pass at the instant the interrupter

contact-points begin to separate when the spark control is set for the most advanced ignition. This position of the crank-shaft is somewhat before its dead-center position for the end of the compression stroke of one of the pistons of the motor. It may be 40 degrees or more before dead center for a small high-speed motor, and 10 degrees or less for a motor which runs at a very slow speed. (See later for determining the corresponding position of the piston.)

Loosen the gear or coupling which drives the magneto rotor so that the rotor can be revolved independently of its driving shaft or gear.

Set the spark control for most advanced ignition, thus moving the timing lever of the magneto as far in the direction opposite the direction of rotation of the magneto rotor as it is intended to be moved while operating.

Move the magneto rotor around in the direction it is to rotate, until the contact-points of the interrupter just begin to separate, and the high-tension distributer arm is in position to direct the secondary current to the cylinder whose piston has nearly completed its compression stroke. Fasten the rotor of the magneto to its driver in the position thus determined.

For a motor which is started by hand cranking, it should be determined whether the latest ignition, as obtained by moving the control to its full retard position, is late enough not to give a back-kick of the crank-shaft when starting the motor. The interrupter contact-points can separate a very short time before the crank-shaft has reached dead center, without causing a back-kick, since the movement of the crank-shaft carries it past dead center before combustion can progress far enough to cause an appreciable increase of impulse pressure on the piston.

The method of disengaging the teeth of the driving gear, as described for timing a timer, can be used if necessary.

Second Method. — Set the crank-shaft of the motor in dead-center position, with one of the pistons at the end of its compression stroke.

Loosen the timer rotor from its driver.

Move the ignition control to its position for latest spark. This moves the timer lever of the magneto to its extreme position in the direction of rotation of the magneto.

Move the magneto rotor to one of the positions shown in Fig. 294, according to the direction of rotation of the magneto, and so that the high-tension distributer is in position to direct secondary current to the cylinder whose piston is at the end of its compression stroke. Fasten the rotor to its driver in the position thus determined.

The distance *E* for any magneto depends on the speed and other conditions of operation. In a small magneto it is some-

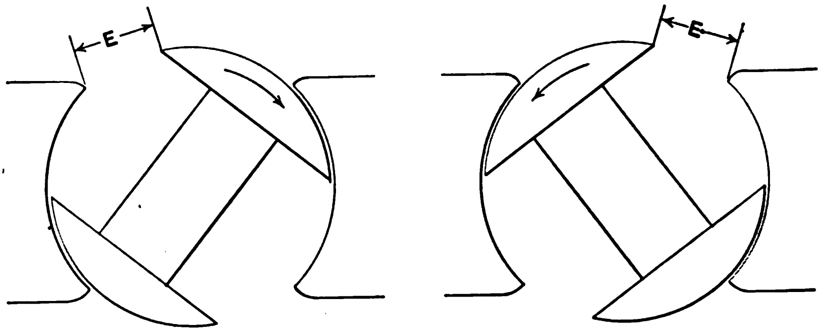


FIG. 294.
Position of Armature for Timing a Magneto by the Retarded Spark Method.

times less than one-fifth of an inch, while in a large one it may be as much as three-fourths of an inch.

The value of *E* should be obtained from the manufacturer's instruction book for the magneto that is to be timed. *E* is, or should be, always greater than *A* of Fig. 293 for a given speed of rotation of any particular magneto.

240. Relative Positions of Crank-Shaft and Piston. — The distance of the piston of a motor from the extreme end of a stroke is frequently given in connection with the timing of ignition. The following formulas can be used for determining this distance in a motor whose cylinder is not off-set to one side of its crank-shaft.

Notation for formulas:

R = radius of crank,
 = one-half the length of the stroke;

n = ratio of the length of the connecting rod to the radius of the crank;

θ = angle, not greater than 90 degrees, of the crank-shaft from its nearest dead-center position;

x = distance of the piston from its extreme position farthest from the crank-shaft, i.e., from its head dead-center position in a single-acting motor of the usual type;

y = distance of the piston from its extreme position nearest to the crank-shaft.

For the distance from the head dead-center position,

$$x = R\left[\text{vers } \theta + n \times \text{versed sine of the angle whose sine is } \frac{\sin \theta}{n}\right].$$

And for the distance from the crank dead-center position,

$$y = R\left[\text{vers } \theta - n \times \text{versed sine of the angle whose sine is } \frac{\sin \theta}{n}\right].$$

The only difference between these two formulas is in the plus and minus signs.*

As a concrete case of application of the formulas, the length of the connecting rod will be taken as four times the radius of the crank. This makes $n = 4$. And the angle of the crank from head dead-center position will be taken as $30^\circ = \theta$. Then, by substituting these values of n and θ in the first formula:

$$x = R\left[\text{vers } 30^\circ + 4 \times \text{vers of the angle whose sine is } \frac{\sin 30^\circ}{4}\right].$$

The versed sine of 30° is .134.

* Either of these two formulas could be used for any position of the crank and the corresponding position of the piston (for any value of θ), but on account of the liability to confusion when using values of θ greater than 90 degrees, it is simpler to limit θ to a maximum of 90 degrees and use both formulas.

The sine of 30° is .500; therefore $\frac{\sin 30^\circ}{4} = \frac{.500}{4} = .125$.

The versed sine of the angle (about 7°) whose sine is .125 is .008.

The last expression, therefore, becomes

$$\begin{aligned} x &= R\,[.134 + 4 \times .008] \\ &= R\,(.134 + .032) \\ &= .166\,R. \end{aligned}$$

And since R = half the length of the stroke, $2\,R$ = length of stroke, and

$$\begin{aligned} x &= .083 \times 2\,R \\ &= .083 \times \text{length of stroke.} \end{aligned}$$

This shows that the piston is .083 = 8.3 per cent of its full stroke from the head end of the cylinder when the crank is 30 degrees from its head dead-center position, and the connecting rod is four times as long as the crank radius, as assumed.

If the stroke of the piston is 6 inches, then the linear distance of the piston from the head end of its stroke is

$$x = .083 \times 6 = .498 \text{ inch,}$$

which is almost half an inch.

For the distance of the piston from the crank end of its stroke when the angle of the crank is 30 degrees from head dead-center,

$$\begin{aligned} y &= R\,(.134 - .032) \\ &= .102\,R \\ &= .051 \times \text{length of stroke.} \end{aligned}$$

And the distance of the piston from the crank end of its stroke is

$$y = .051 \times 6 = .306 \text{ inch}$$

for the assumed 6-inch stroke.

The positions of the piston for any crank angle up to 90 degrees can be found by substituting the assumed value of the crank angle in the equations and solving in a similar manner.

CHAPTER XXVIII.

IGNITION-SYSTEM FAULTS AND REMEDIES.

241. Defects and Conditions in the Ignition System Which Cause Faulty Ignition. — In some cases a remedy is given for the trouble mentioned, but in others the remedy is so obvious that it is not mentioned.

In the Igniter.

242. Spark-gap too wide or too small. The spark-points sometimes burn off in magneto ignition systems.

Carbon and oil deposit in the spark-gap or on the insulation. Caused by too much lubricating oil or a poor quality of oil, or by too rich a mixture.

Water on the spark-points. Generally due to a cracked or porous cylinder. The water may be due to some other source when the engine has been standing idle for a considerable time.

Loose contact-points in a make-and-break igniter.

Porcelain insulation cracked or chipped. Steatite insulation seldom cracks or chips. An igniter in this condition may give a good spark or arc while the igniter is removed from the motor, but when in place the defect may cause a short circuit so as to prevent the formation of an ignition arc or spark. This is because the electric resistance of the spark-gap is greater in the compressed charge in the motor than in the open air. Porcelain insulation that is chipped at the portion outside of the motor will generally not cause a short circuit while the chipped surface is still clean, but if it is touched by one's hand while working around the motor, so as to leave dirt on the chipped surface, the dirt is apt to cause a short circuit sufficient to prevent ignition, especially when the motor is working on full

charges, although the igniter may give a good spark while removed from the motor. This short circuit is most apt to occur when the chipped surface extends from the insulated spindle to some of the other metallic parts of the igniter.

Mica insulation loose so that dirt can collect between the layers, or laminations, of the mica. The behavior of an igniter in this condition is much the same as that of one with solid insulation that is cracked or chipped. It is generally not possible to clean mica that has become fouled in this manner. It is generally advisable to discard an ordinary jump-spark plug that has this defect, but in the case of a large make-and-break igniter the better plan is to put in new insulation.

Mica insulation rough from scraping or crumbling. Crumbled mica is worthless. It has somewhat the appearance of worm-eaten wood. But when the surface of the mica is only roughened it may be polished in some cases. The rough surface collects dirt and the final result is a short circuit in the igniter.

Burned and pitted contact-points. This prevents the contact-points of a make-and-break igniter from making good metallic contact with each other. Consequently the full strength of current does not flow and the arc is therefore weak. This condition causes sluggish action of a magnetically operated igniter.

Loose packing. This allows some of the compressed charge to escape. A hissing sound can sometimes be heard. Lubricating oil put around the igniter will sometimes indicate the leak by bubbles or by being blown off at the leak. Put new packing in a high-tension plug. A string of asbestos fiber wrapped around a fine copper wire (a commercial product) is suitable in the absence of the regular form of packing for small plugs. A gasket made of sheet copper bent over so as to form a deeply grooved ring with asbestos in the groove (copper-asbestos gasket or washer) is convenient when there is no rubbing action against the gasket. In a make-and-break igniter it may be only necessary to tighten the movable electrode against its bearing, in order to take up end wear.

Operating parts worn so as not to separate the contact-points wide enough to draw a good arc.

In the Spark-Coil.

243. Contact-points at the trembler burned or pitted so as not to make good electric contact. The most usual indication of this condition is irregular ignition, sometimes followed by complete stopping of ignition. A contact-point is pitted when it has small depressions, or pits, burned into it.

Water or dirt on contacts at trembler. Water generally stops ignition completely. Dirt has much the same effect as badly pitted contact-points.

Contact-points stuck together by fusing. This sometimes happens when one coil acts for several cylinders. It also sometimes happens when there is excessive sparking at the contact-points of a trembler coil that is used for only one cylinder.

Excessive sparking at trembler contacts. May be due to too high voltage in the primary circuit, as when there are too many cells in the battery. Cut out one or two cells unless the number is known to be correct. All spark-coils do not operate properly at the same voltage. If reducing the number of cells does not stop excessive sparking, then the trouble is probably due to the condenser not performing its function correctly, as on account of its insulation being broken down or one of its connecting wires broken or loose. If there is, or should be, a separate ground wire for the condenser, see that the wire is in place. Excessive sparking as stated, may also be due to defective insulation in either the primary or secondary winding of the coil.

Insulation broken down in transformer coil or condenser. Indicated by excessive sparking at trembler contacts. May be caused by too high a voltage in the primary circuit. Also by allowing the trembler to operate while the secondary circuit is disconnected, especially where there is no safety spark-gap as part of the coil. Repair should be made by an expert, or the defective coil replaced by a new one.

Loose contact-point on trembler. Unusual. Causes irregular ignition. Rivet or solder with hard solder (one which does not melt easily), such as that used for silver.

Trembler spring bent. May change rate of vibration or entirely prevent it. Straighten or put in a new spring.

Difference of lag in producing ignition sparks when two or more spark-coils are used on one motor. Adjust the tremblers to vibrate at the same rate, as indicated by the pitch of the sound.

In the Reactance Coil (Kick-Coil).

244. Defective insulation. May be caused by using too high voltage. Causes a weak arc at the contact-points of the make-and-break igniter, or entirely prevents arcing. Dirt between the terminals may have the same effect. A kick-coil seldom gives trouble, however.

In the Timer.

245. Dirt or grit between contact-pieces prevents closing the circuit and causes rapid wear.

Hard grease between roller contact-points prevents closing the circuit. Some grease that is very soft while warm becomes quite hard when cooled, as when the motor stands over night in a garage that is not warmed. Use oil or semifluid grease.

Oil between contact-points which close the circuit by pressure only (without rubbing or rolling) may prevent good electric contact.

Keep oil from contact-points.

Circuit closed at wrong time on account of worn or loose parts.

Stationary timing part worn loose so as to wabble and shake about. This is apt to cause irregularity in the time of closing the circuit.

Stationary rollers loose on pins which support them. In some designs where the rotor strikes stationary rollers to close the circuit, the rollers, when worn loose, move about so as to vary the time of closing the circuit.

Failure to close the circuit on account of worn or binding parts.

Spring weak or broken.

Brush binding or sticking in its holder.

Rotor shaft does not have good electric connection with the metal of the motor. Causes imperfect closing of the circuit, and sometimes there may be complete failure to close it. Consequently the ignition spark or arc is weak at times or fails entirely.

Circuit not closed at the same instant relative to the position of each piston in its stroke. May be due to faulty construction or to worn parts.

Insulated contact-piece of the rotor not in continuous contact with the part (shaft) on which it is mounted. Generally due to a loose screw or other fastening. Causes weak spark and missing of the spark.

Rotor very loose on its shaft. In some designs the rotor is fastened to its shaft by a set-screw in such a manner that when the set-screw works loose the rotor can gradually move around on the shaft. Such a condition varies the time of ignition to an extreme amount. If this moving around occurs slowly, it is necessary to keep advancing the spark at the corresponding rate to keep the motor running. After that the continued moving of the rotor on its shaft will prevent ignition generally.

In the Magneto.

246. Dirt (carbon dust, particles of metal) in the distributer. Due to wear of rubbing parts. Clean with a bristle brush and piece of cloth without using any liquid if possible. Use kerosene if found necessary to remove the dirt. Do not oil if a carbon brush is used. Put a small amount of oil on the rubbing surfaces with a cloth if a metal brush is used to rub against metal.

Dirt in the interrupter. Clean with a bristle brush and a cloth. It is better not to use gasoline, for although it is excellent for cleaning, it leaves the rubbing surfaces in poor condition. If the gasoline is used, care should be taken to see that the rubbing surfaces are coated with a small amount of lubricating oil. Oil the rubbing surfaces very sparingly, if at all. The interrupters of some magnetos are self-oiling. Others do not require any lubricant. This is the case when one of each pair of rubbing surfaces is of wood fiber or some similar material. The inter-

rupter lever is sometimes bushed with fiber where it rocks on its supporting pin.

Contact-points of interrupter burned or pitted. Dress smooth and flat with dead-smooth file.

Oil, grease, or water between contact-points of interrupter. Grease prevents the points from making good contact with each other. Oil is very apt to do the same. Water prevents the interruption of the current.

Weak spring on interrupter lever. Does not press the contact-points together firmly. Put in a new spring or bend the old one so that it will press the contacts together harder. If a steel spring is very soft it may be retempered. The retempering can be quickly done by one familiar with heat treatment of high-grade steel.

Interrupter lever binds on its pin. Refit. This should be done by a skilled mechanic. A reamer of the proper size will enlarge the hole slightly and leave it in good condition. A twist drill may be used, but is not so good. In an emergency a fine-cut round file may be used to enlarge the hole in a fiber bushing. For hardened metal, a piece of fine-grained emery cloth, or of crocus cloth, wrapped around a wire, can be used. The part should be very carefully cleaned afterward. The pin which supports the lever generally cannot be removed conveniently for reducing its diameter.

Interrupter contacts do not separate to the proper distance. Adjust them.

Interrupter contacts do not separate at the proper time relative to the position of the armature or inductor, according to which is the rotor. This cannot occur in a magneto whose interrupter is fitted to a definite position, and which was properly determined when the machine was made. Otherwise adjust the interrupter to its proper position.

Distributer not in proper position relative to the interrupter. This can be corrected by shifting the gears which drive the distributer relative to each other when there are such gears and when the interrupter and distributer are on separate shafts. Take the gears out of mesh and advance or retard one relative

to the other by the amount of one tooth, or several teeth, as seems necessary.

Roller or rollers of interrupter worn flat on one side. If the roller can rotate, it will cause the contact-points to separate farther at one time than at another.

Too much lubricating oil. If the oil reaches the insulation of the armature, it is apt to destroy its insulating property to some extent, and a short circuit may result.

Brush (carbon) worn out or binding in its holder so as not to make good contact. File the brush a little smaller if it binds.

Brush spring weak. Stretch it if it is a coiled compression spring. Cut off some of it if it is a coiled tension spring. Bend a flat spring so that it will press harder against the brush or its holder, as the case may be. Retemper a steel spring if thought necessary.

Condenser insulation defective, or the condenser has loose connection. Excessive sparking at the interrupter is the result of either of these defects. The connection can sometimes be easily tightened or repaired, but the defective insulation requires the attention of an expert.

Armature insulation damp or wet. Remove the armature and bake it in a moderately warm place for a day or more. Then varnish the insulation with waterproof insulating varnish if it appears necessary. A magnet keeper should be placed across the pole-pieces when the armature is removed, and left there till the armature is replaced. A flat piece of soft steel a quarter-inch or so thick will answer. Several pieces of small, flat bar steel or iron can be used in the absence of a larger piece.

Armature insulation defective. Requires the attention of an expert.

Poor ground connection between armature and frame of motor. This of course does not include machines in which the armature winding is intended to be entirely insulated from the frame. Is apt to occur in a machine which has no ground brush for a rotating armature. May be due to the ground brush becoming worn out, or to a loose connection between the brush and ground.

Bearings worn so that rotor strikes the pole-pieces.

Loose driving gear or coupling. Tighten and fit new pin or key if the old one is worn.

Defective switch. May make a partial ground connection when the switch is open and there should be no such circuit. The switch may be only in need of cleaning.

Magnets have become weak. Sometimes caused by removing the rotor (armature or inductor) without putting a keeper across the pole-pieces or the ends of the magnets. The magnets can be remagnetized by wrapping insulated wire around them in the manner indicated in Fig. 50. It may be necessary to take a compound magnet apart and deal with the magnets individually. The wire can be wound from end to end of the magnet if desired, or it may be put on only one leg. A coil wound on a non-magnetic spool of a shape to fit fairly closely to the bar of the magnet is convenient. If a spool is put over each leg, the connection between the spools must be made so that the current will flow through them in the directions indicated in Fig. 50. A piece of iron or soft steel should be placed across the ends of the magnet legs in the manner of a keeper. The electric current needs to flow only a second or so, and should then be decreased gradually. A gradual decrease of current can be obtained by slowly separating two wire-ends so as to draw an arc that gradually decreases in volume as the ends are moved farther apart; or by separating the wire-ends gradually under impure water, such as that containing salt or acid. Several applications of current may be advantageous. The strength of the magnet can be tested by its lifting power, as by placing a heavy piece of steel or iron on weighing scales, and noting the decrease of scale reading when the magnet is applied to lift the piece, after the current has been stopped.

The current used is large enough when an increase of it produces no further increase in the strength of the magnet, as measured after the current is discontinued. Care should be taken to put the individual magnets together so that all of the north poles are next to the same pole-piece.

In the Dynamo.

247. Excessive sparking at the brushes. Brush does not make good contact with the commutator. Brush worn crooked. Roughened commutator. May also be due to some of the causes mentioned below.

Armature coil burned out or its insulation defective. Causes excessive sparking at the brushes and at one or two segments of the commutator. The commutator segments connected to the defective coil appear burned at the edges.

Commutator burned along edges of all segments. Brushes not set in proper position, thus causing sparking and burning at all of the segments. Adjust the brush-holder rotatively so as to bring the brushes in proper position if possible. Some dynamos have no means of adjusting the brush-holder in this manner.

Commutator worn out of round. Causes sparking. If very bad, turn true in a lathe. Can be trued somewhat, and smoothed, by sandpapering with fine-grained sandpaper, after removing the brushes from contact with the commutator.

Grease and dirt on commutator. Causes sparking and burning.

Brush-holder dirty. Causes a partial short circuit and sometimes heating of the armature by the excessive amount of current that flows on account of the partial short circuit. Sparking and burning of the commutator may accompany this action.

Field-coil connection broken. This may be inside of the insulation, but only in unusual cases. Prevents the generation of current completely if the ends are separated at the break. But if the ends touch each other, there may be indifferent generation of current.

Other troubles may be of the same general nature as some of those in a magneto. (See "In the Magneto" immediately preceding.)

In the Battery.

248. Exhausted dry cells. If there are two dry batteries and both are exhausted so that neither will supply sufficient current, put the two batteries in series with each other. As a last resort, dig some of the sealing compound from the top of each cell so

as to expose the blotting paper, and put water in each cell, or sal ammoniac and water solution such as is used for the electrolyte. Keep the paper covering of the cells dry.

Wet coverings on dry cells. If the paper covers become wet, keep the cells separated so that the covers cannot touch each other. Do not let the cells rest against metal or water-soaked wood.

Storage battery discharged. Indicated by low voltage of battery *while discharging*. Recharge the battery. Do not put storage batteries in series with each other to secure a higher voltage after the battery voltage has become low, as just stated, except in extreme emergency.

Wrong connections between cells or batteries. A reversed cell reduces both the voltage and current of the battery. Some wrong connections cause the battery to run down rapidly.

Cells loose so that they can shake about. Is apt to loosen the connections or break them.

Loose connections between cells. Causes erratic ignition. Tighten the nuts of dry cells with pliers, or flatten the nut slightly with a hammer so that it binds on the thread. The nut may be secured with a drop of solder. These methods are suggested for dry cells only.

Corroded terminals. These are apt to make the connection poor on account of high resistance. Clean and brighten the metal. Cover with vaseline or varnish.

Dirt on insulation between terminals. Causes leakage and waste of current, especially if the dirt is moist.

Metal of adjacent cells in contact. This may occur between the terminals or metal cans of dry cells. Wastes current and reduces voltage.

Metal tools or other metallic appliances on and against the battery is apt to cause a short circuit.

Electrolyte low in cells, or not of proper strength (specific gravity, density).

Sediment in bottom of the cells of a storage battery. The battery runs down rapidly. Causes excessive heating of the battery in extreme cases.

In the Connections.

249. Loose strand of wire cable. Is apt to touch some metallic part so as to make a ground connection or a short circuit. The strands of the cable should be twisted together where it is bared to fasten to a binding post. It is sometimes advisable to solder the strands together where they are bared.

Swinging or vibrating wire. If the wire strikes or rubs against anything, the insulation will generally be worn off. Contact with a metal part and intermittent short-circuiting may result, thus causing irregular ignition.

Oil on insulation destroys it.

Loose binding screws and joints.

Mixture lean or too rich.
Lubrication insufficient or wrong kind of lubricating oil.
Valves do not open wide enough.
Valve timing wrong.
Clogged exhaust passages.

Spark Control Must be Advanced More Than Usual and Motor Behaves Erratically.

259. This is characteristic of a loose timer rotor, which is so loose as to drop back part of a rotation on the shaft or other part that drives it. Irregularity in the time of ignition, which is not helped by advancing the control excessively, may be due to other loose parts of the timer or corresponding device.

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